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Front Cover: The terrestrial orchid *Didymoplexis pallens* is known from only six locations in the Northern Territory. This leafless saprophyte survives most of the year as an underground tuber, emerging early in the wet season. (Don Franklin)

Rear Cover: The elusive Chameleon Dragon *Chelosania brunnea* has been recorded from scattered locations in the Top End and Kimberley, with the majority of records from Kakadu National Park. (Alex Dudley)

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New location records for some butterflies of the Top End and Kimberley regions

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Abstract

We report 52 new locations in north-western Australia for 22 species of butterfly. Six records are of three species rarely reported in the region, the Fiery Jewel *Hypochrysops ignita*, the Two-spotted Line-blue *Nacaduba biocellata* and the Long-tailed Pea-blue *Lampides boeticus*. Records of the Orange Ringlet *Hypocysta adiante*, Spotted Pea-blue *Euchrysops cnejus* and Small Dusky-blue *Candalides erinus*, species previously reported as occurring patchily in north-western Australia, are sufficient to suggest that they occur throughout the region. The ease with which new location records were obtained beyond the Darwin area suggests that much remains to be learned about the distribution of butterflies in the remoter parts of north-western Australia.

Introduction

For butterflies, generic Australia-wide distribution maps covering all species have been available for over three decades (Common & Waterhouse 1981, and earlier editions). Dunn and Dunn (1991) mapped over 90 000 specimen records continent-wide. More recently, Braby (2000) has presented updated generic distribution maps incorporating Dunn and Dunn's data set and other records. Nevertheless, Braby noted that "In many cases, gaps in the ranges shown .... do not necessarily reflect natural disjunctions". Braby goes on to name the arid zone, but surprisingly not the monsoon tropics, as a primary area of deficient reporting.

Knowledge of invertebrate distributions has traditionally been and largely remains based on collections, with the exception of a few distinctive species (e.g. Wilson *et al.* 2003). The value of observational records for an entire faunal group has been amply demonstrated for birds (Blakers *et al.* 1984, Barrett *et al.* 2003), both of which have spawned numerous subsidiary analyses (e.g. Franklin *et al.* 2000, Griffioen & Clarke 2002). However, harnessing such records is dependent upon the ability to accurately identify species in the field, a process that for butterflies in Australia has been enhanced by the production of a handbook (Braby 2000) and more recently, a field guide (Braby 2004). Braby acknowledges the use of "recording" as well as collections

in the preparation of his maps, and Puccetti (1991) provided a tangible example of the value of observation-based recording of butterflies.

In this note, we present records of butterflies observed in the Top End and Kimberley region of monsoonal northern Australia which are *c.* 100 km or more beyond the ranges mapped by Braby (2000).

Methods

Butterfly records were obtained during formal surveys and as incidental sightings: (1) during brief visits to the Victoria River District (Northern Territory) and Kununurra area (Western Australia) by BM and MM in May and August 2003; (2) during a 3-day survey of the butterfly fauna of Elsey National Park and vicinity by DF, BM and others in May 2004; and (3) in brief explorations of the butterfly fauna incidental to other research, during a series of expeditions to remoter parts of north-western Australia, including sub-coastal areas of the Gulf of Carpentaria, northern Arnhemland, and central and north Kimberley, during the dry season of 2004 (DF).

All the species reported here are, with appropriate experience, readily identified as adults either in the field or in the hand, skills that we have developed intensively over the last three years during surveys in the vicinity of Darwin. Records of lycaenids are based on either close examination of netted specimens, or in a few cases, close examination of individuals at rest in the field. Most of our nymphalid records, along with the sole papilionid record, are based on sightings of butterflies in flight or at rest. In all cases, we have given due consideration to possible alternate identifications based on species known to occur in north-western Australia (Braby 2000), and in most cases, we had prior familiarity with both the species reported and of similar species. Unfamiliar species and most lycaenids were checked in the field against the illustrations of Braby (2000), the identification process being enhanced by a field key developed by one of us (DF) based primarily on the descriptions, identification notes and illustrations in Braby (2000). The field guide of Braby (2004) was not available during the study period. We have excluded records where there might be a reasonable call for a confirmatory voucher specimen (e.g. many Hesperiidae).

We have not attempted to identify individuals to subspecies level. With the possible exception of the Fiery Jewel *Hypochrysops ignita*, it seems unlikely that information about subspecies, were it available, would be of particular interest because the records presented here are nested within more general distributions that involve only a single subspecies.

Results

Fifty-two new locations involving 22 butterfly species are summarised in Table 1, including 41 records of 19 species in the Northern Territory and 11 records of seven species in Western Australia. Two species observed in Western Australia, the Dusky

Knight *Ypthima arctous* and Chocolate Argus *Junonia hedonia*, were not reported from that state by Braby (2000), but Grund and Hunt (2001) reported both species from Kalumburu and considered the Dusky Knight to be "common" there. Most locations were in the order of 100-200 km beyond areas indicated by Braby (2000), with the greatest being a *c.* 600 km range extension west-south-westwards for the Chocolate Argus. The record of the Long-tailed Pea-blue *Lampides boeticus* at Gove Peninsula is a *c.* 400 km range extension from previous reports near Borroloola and Darwin.

Discussion

Three of the observed species, the Two-spotted Line-blue *Nacaduba biocellata*, Long-tailed Pea-blue and Fiery Jewel, are uncommonly reported from any location in monsoonal north-western Australia (Braby 2000), being more widespread in inland, southern and/or eastern Australia. The Two-spotted Line-blue has been previously reported in the region from only the vicinity of Darwin and in the catchment of the Prince Regent River in Western Australia. However, our four new localities suggest that it may be much more widespread, as suggested by Braby, with its small size resulting in it being readily overlooked. The Fiery Jewel has previously been reported in the Northern Territory from several locations in the vicinity of Darwin, and once each from the vicinity of Katherine and in east Arnhemland. The single, striking individual reported here from Kakadu National Park was observed from about 1 metre for several minutes as it perched on the foliage of an understorey sapling in tall woodland of Darwin Stringybark *Eucalyptus tetrodonta* and Darwin Woollybutt *E. miniata* that had not been burnt for several years. The Long-tailed Pea-blue is more widely dispersed in the region than the previous two species, but nevertheless uncommonly so. In addition to the report in Table 1 from Gove Peninsula, DF observed it closer to previously reported occurrences, at El Questro Station in Western Australia, where two individuals were seen and one netted in green grass near the bank of the Pentecost River.

The remaining 19 species are widespread in parts of monsoonal north-western Australia (Braby 2000), and most are fairly common to abundant in the Darwin area (pers. obs.). The records presented here are thus not particularly surprising. Some, however, may provide basis for more comprehensive generalisations about distributions. The numerous locations for, and frequent abundance of the Orange Ringlet *Hypocysta adiante*, Spotted Pea-blue *Euchrysops cnejus* and Small Dusky-blue *Candalides erinus*, including many records not listed here because they were in or close to previously reported occurrences (Braby 2000), suggest when combined with Braby's distribution maps that these species occur more or less throughout the tropical savannas of north-western Australia. At many of the sites where we observed the Small Dusky-blue, its food plants – several species of dodder-laurel (*Cassytha*) – were also prevalent. Numerous sightings of the Chocolate Argus suggest a similarly widespread distribution for the Top End of the Northern Territory at least.

Table 1. New location records for some Top End and Kimberley butterflies. Checklist order, scientific nomenclature, and common names follow Braby (2000). NT = Northern Territory; WA = Western Australia; VRD = Victoria River District (NT). Bracketed dates are inclusive periods where dates of individual sightings were not noted. Notes enclosed thus " " are extracts from DF's diary.

Family / species / location	Date	Notes
Papilionidae *Cressida cressida* (Clearwing Swallowtail)		
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	"common in woodland"
Nymphalidae *Melanitis leda* (Evening Brown)		
WA: El Questro Stn. - Amalia Gorge 15°57'S, 128°02'E	14/8/2004	"sheltering on ... ground ... in heavy shade"
Nymphalidae *Mycalesis sirius* (Cedar Bush-brown)		
NT: Central Arnhem Rd 145 km from Nhulunbuy *c.* 12°45'S, 136°14'E	9/7/2004	one, in creekline grass
NT: Liverpool R. crossing, Oenpelli-Maningrida Rd 12°21'S, 134°07'E	20/7/2004	one, in floodplain grass
Nymphalidae *Ypthima arctous* (Dusky Knight)		
WA: Ellenbrae Stn 15°59'S, 127°04'E	3/8/2004	one
WA: Barnett River Gorge 16°32'S, 126°07'E	13/8/2004	one
Nymphalidae *Hypocysta adiante* (Orange Ringlet)		
NT: Lorella Springs Stn Hstd 15°44'S, 135°39'E	12/6/2004	moist grass near creek
NT: Limmen Nat. Pk - Butterfly Springs 15°38'S, 135°28'E	14/6/2004	in moist grass near creekline
NT: Central Arnhem Rd, 145 km from Nhulunbuy *c.* 12°45'S, 136°14'E	9/7/2004	one, grass near creek
NT: Central Arnhem Road at Flat Rock Ck *c.* 12°55'S, 135°20'E	17/7/2004	one, grass near creek
WA: Barnett River Gorge 16°32'S, 126°07'E	13/8/2004	
WA: Bamboo Ck, Gibb River Rd. 15°53'S, 127°21'E	13/8/2004	creekline
Nymphalidae *Polyura sempronius* (Tailed Emperor)		
NT: Victoria River Roadhouse 15°37'S, 131°07'E	14/8/2003	
Nymphalidae *Cethosia penthesilea* (Orange Lacewing)		
NT: Ramingining area *c.* 12°15'S, 134°58'E	*c.* 6/7/2004	
Nymphalidae *Junonia hedonia* (Chocolate Argus)		
NT: Wollogorang Stn - Settlement Ck 17°13'S, 137°56'E	10/6/2004	2 or 3 in one creekside location
NT: Lorella Springs Stn Hstd 15°44'S, 135°39'E	(12-13)/6/'04	
NT: Roper Bar 14°43'S, 134°31'E	16/6/2004	"fairly common ... upper ... floodplain forest"
NT: Gove Pen. - Gayngaru 12°11'S, 136°47'E	11 & 14/7/'04	"locally very common"
WA: Adcock Gorge 16°55'S, 125°46'E	12/8/2004	"one at swampy creek"
Nymphalidae *Tirumala hamata* (Blue Tiger)		
NT: Gove Pen. nr Garanhan 12°20'S, 136°56'E	10/7/2004	"one, vine-thicket"

continued on next page

Nymphalidae *Danaus affinis* (Swamp Tiger)		
NT: Limmen Nat. Pk - Towns R. fishing camp 15°02'S, 135°14'E	15/6/2004	two together, near river bank
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	a few
NT: Gove Pen. - Gayngaru 12°11'S, 136°47'E	(11-14)/7/'04	a few
Lycaenidae *Hypochrysops ignita* (Fiery Jewel)		
NT: Kakadu Nat. Pk - 25 km NE of Munmarlary 12°21'S, 132°40'E	28/8/2004	one
Lycaenidae *Arhopala centaurus* (Purple Oak-blue)		
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	
NT: Gove Pen. - Gayngaru 12°11'S, 136°47'E	(10-16)/7/'04	one
Lycaenidae *Candalides erinus* (Small Dusky-blue)		
NT: Elsey Nat. Pk - Mulurark 14°57'S, 133°13'E	2/5/2004	one
NT: Mataranka - Elsey Cemet. 15°04'S, 133°07'E	2/5/2004	
NT: Elsey Nat. Pk - Salt Ck 15°01'S, 133°14'E	3/5/2004	a few
NT: Caranbirini Cons. Res. 16°17'S, 136°05'E	6/6/2004	"several ... sandstone"
NT: Roper Bar 14°43'S, 134°29'E	16/6/2004	"abundant ... creekline"
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	abundant
NT: Gove Pen. - Gayngaru 12°11'S, 136°47'E	(11-14)/7/'04	abundant
WA: Ellenbrae Stn 15°59'S, 127°04'E	3/8/2004	
WA: Mitchell Plateau c. 14°45'S, 125°40'E	(5-6)/8/'04	
Lycaenidae *Nacaduba biocellata* (Two-spotted Line-blue)		
NT: Jasper Gorge, VRD 16°02'S, 130°41'E	3/5/2003	
WA: Hidden Valley 15°46'S, 128°45'E	15/8/2003	
NT: nr Pine Creek 13°49'S, 131°50'E	8/6/2003	
WA: El Questro Stn 15°57'S, 128°02'E	16/8/2004	a few in creekbed
Lycaenidae *Prosotas dubiosa* (Purple Line-blue)		
NT: nr Jasper Gorge, VRD 16°00'S, 130°39'E	4/5/2003	
Lycaenidae *Catopyrops florinda* (Speckled Line-blue)		
WA: Ellenbrae Stn 15°59'S, 127°04'E	3/8/2004	one
Lycaenidae *Lampides boeticus* (Long-tailed Pea-blue)		
NT: Gove Pen. - Gayngaru 12°11'S, 136°47'E	14/7/2004	one
Lycaenidae *Zizeeria karsandra* (Spotted Grass-blue)		
NT: Jasper Gorge, VRD 16°02'S, 130°41'E	3/5/2003	
Lycaenidae *Zizina labradus* (Common Grass-blue)		
NT: Nhulunbuy & Gayngaru 12°11'S, 136°47'E	(11-14)/7/'04	lawn & grassy area
Lycaenidae *Famegana alsulus* (Black-spotted Grass-blue)		
NT: Jasper Gorge, VRD 16°02'S, 130°41'E	3/5/2003	
NT: nr Wollogorang Stn Hstd 17°13'S, 137°57'E	10/6/2004	
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	"fairly common"
Lycaenidae *Euchrysops cnejus* (Spotted Pea-blue)		
NT: nr Wollogorang Stn Hstd 17°13'S, 137°57'E	10/6/2004	locally abundant
NT: Lorella Springs Stn 15°44'S, 135°39'E	(12-13)/6/'04	
NT: Roper Bar 14°43'S, 134°31'E	16/6/2004	
NT: Gove Pen. - Daliwuy 12°21'S, 136°55'E	(10-16)/7/'04	"common"
Lycaenidae *Freyeria putli* (Jewelled Grass-blue)		
NT: Jasper Gorge, VRD 16°02'S, 130°41'E	3/5/2003	

Records from northern Arnhemland of the Cedar Bush-brown *Mycalesis sirius*, Orange Ringlet and Orange Lacewing *Cethosia penthesilea* suggest continuity across the north coast of the Northern Territory between previously reported populations in the north-western Top End and at Nhulunbuy. Records of the Orange Ringlet in Western Australia may indicate continuity between previous reports from the central-west and east Kimberley, especially as DF also observed the species at other intermediate locations closer to the previously reported populations, at Adcock Gorge and El Questro Station (see Table 1 for coordinates) and Manning Gorge (16°38'S, 125°55'E). Records of the Purple Line-blue *Prosotas dubiosa*, Spotted Grass-blue *Zizeeria karsandra*, Black-spotted Grass-blue *Famegana alsulus* and Jewelled Grass-blue *Freyeria putli* in the Victoria River District may indicate continuity between previously-reported populations in the Kununurra area of Western Australia and those of the north-western Top End.

In the course of three years of active field study of butterflies around Darwin, neither we nor any colleagues have obtained records of species new to the area. However, upon travelling to remoter areas, new location records were very readily obtained; metaphorically, we *tripped* over interesting records. This indicates a steep decline in the intensity of previous surveys away from the main settled areas, and that very much remains to be learned about butterfly distributions in the larger portion of north-western Australia. It also indicates that skilled observers, whether amateur or professional, can contribute greatly to our geographical understanding of butterflies simply by visiting and surveying remoter areas, carefully self-vetting records for accuracy, and then placing interesting observations on the public record.

Acknowledgements

Our joy in developing an acquaintance with the butterfly fauna of monsoonal Australia has been shared with Heather Ryan, Deb Bisa, Arthur & Sheryl Keates, Kim McLachlan and occasionally other people, and interactions with these observers have greatly enhanced our identification skills. Soren Faurby, Arthur & Sheryl Keates and Niven McCrie assisted with the survey of Elsey National Park. Christine Maas drew DF's attention to the most exciting of the records presented here, the Fiery Jewel. The survey of Elsey National Park was conducted under Parks & Wildlife permit no. 17457.

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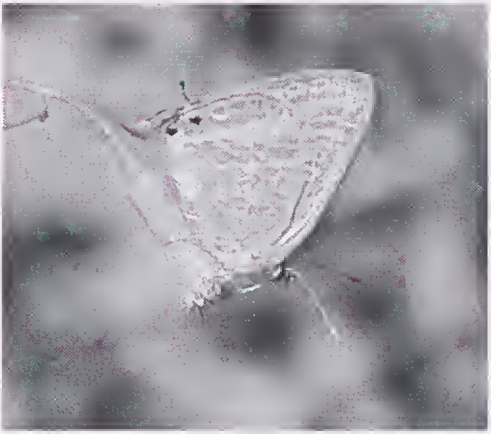

Sightings of the Long-tailed Pea-blue *Lampides boeticus* (left, Max Mace) and Swamp Tiger *Danaus affinis* (below, Don Franklin) near the Gulf of Carpentaria are new locations for these species.

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Do predators affect the survival of *Macaria pallidata* larvae? Implications for biological control of *Mimosa pigra* in the NT

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Abstract

There have been few studies investigating whether predators can affect the survival of insects that have been introduced into new regions. To address this, ants and birds were excluded from mimosa (*Mimosa pigra*) plants that had larvae of a leaf-feeding geometrid moth, *Macaria pallidata* placed on them. The moth is used as a biological control agent against mimosa in the Northern Territory. More larvae were observed when ants and birds were excluded. The ants present were generalists, probably attracted to mimosa by the nectar it supplies at the base of the leaves.

Introduction

Few studies have investigated factors influencing the establishment of insect populations introduced into new areas. Failure of an insect to colonise a new area is commonly attributed to climatic variables, often without any data to support such a claim (Clarke 2001). The actual causes of failure are rarely studied, but can have important implications for biological control programs (Day *et al.* 2004). Such knowledge should be used when selecting future biological control agents, considering the large costs associated with finding, testing and introducing them.

The macaria moth *Macaria pallidata* (Lepidoptera, Geometridae) is a biological control agent released against the weed mimosa (*Mimosa pigra* L) in Australia. Macaria was identified as a potential biological control agent against mimosa, but was originally ignored because it was considered too vulnerable to predators and parasitoids (Harley *et al.* 1995).

Female macaria lay eggs on leaves and stems, and larvae feed for c. 13 days. Larvae are soft-bodied, slow moving "looper" caterpillars that grow up to 2 cm long and feed externally on mimosa leaves (Heard *et al.* 2001). Larvae go through five instars then form prepupae, which are obviously shorter, thicker and darker coloured. Most larvae descend to the ground to pupate. Larvae drop on a silken thread when disturbed (Heard *et al.* 2001, B. Routley, pers. comm.).

Mimosa has been the target of a large, ongoing biological control program since 1979 (Paynter & Flanagan 2002). It is an invasive weed that infests approximately 800 km^2 of Top End floodplains, and has the potential to spread throughout much of tropical Australia (Walden *et al.* 2002). To date, twelve species of insects and two species of fungi have been released against this weed. Seven of these insect species have established (N. Ostermeyer, unpubl.). Macaria was the first insect released that primarily attacks mimosa leaves. Mimosa in the Northern Territory now grows more slowly and produces considerably less seed than it did before biological control (Paynter & Flanagan 2002, Paynter in press).

Initial releases of macaria in Australia (between June 2002 and December 2004) appeared to be unsuccessful – no insects could be found at release sites, despite extensive searches (B. Routley, unpubl.). Predators such as ants, spiders and birds have been observed eating and disturbing caterpillars in the Top End, and birds have also been observed eating macaria adults. This experiment aimed to determine if ants and bird predators do influence survival of macaria larvae.

Methods

The experiment was conducted near Beatrice Hill Lagoon (12° 33' S, 130° 18' E), on the Adelaide River floodplain. The site was previously dominated with spike-rushes (*Eleocharis* spp.) (Story 1969), and much of the area was invaded by mimosa in the 1970s (Braithwaite *et al.* 1989). Since 1989 the inundated areas have been taken over by the introduced pasture grasses *Hymenachne amplexicaulis* and *Brachiaria mutica*, leaving little *Eleocharis* remaining.

Mimosa planted in 1999 was used for the experiment. These plants had been planted for previous experiments, and were spaced 3 m apart. To make plants more homogeneous and improve the probability of finding insects, plants were trimmed to *c.* 1.5 m high one month before the experiment commenced. To ensure the ant exclusion treatment was effective, all vegetation touching each plant was removed.

Four treatments were applied randomly to mimosa plants:

1. Ants were excluded by manually removing all ants seen, then applying sticky gel ("Tac-gel", Rentokil) around the base of each plant. This gel was inspected several times, and any large sticks or leaves removed. There were six replicate plants used in this treatment.

2. Birds were excluded with commercial bird netting, which was set up around the plants but not touching foliage. It was not known which bird species were likely to eat larvae (eight replicate plants).

3. Plants had both ants and birds excluded (seven replicate plants).

4. A control group was left untouched (seven replicate plants).

Fifty larvae (third to fifth instar) were placed randomly on the foliage of each plant on 7 November 2002. Larvae on each plant were counted for 5 minutes on 8, 11 and 13 November. The experiment was terminated on 13 November, when no larvae were observed and all larvae would have pupated. Two observers did all the larvae counting, and were assigned plants at random. To test for differences between observers, both observers counted larvae on 12 plants on 8 November.

A sample of ants from each plant was collected on 6 November and identified soon after. There was no specific survey of bird species present in the area.

The number of larvae counted on 8 and 11 November were compared between treatments using generalised linear models with Poisson error distribution, after first removing effects of the person counting larvae by treating this as an additional variable, and checking for overdispersion.

Results

One day after placing larvae on plants, more larvae were found on plants where ants had been excluded (Figures 1, 2, d.f. = 1, $\chi^2 = 32$, $p < 0.0001$). Excluding birds also affected larval survival (d.f. = 1, $\chi^2 = 3.8$, $p = 0.009$). There was no important interaction between excluding birds and excluding ants (d.f. = 1, $\chi^2 = 1.0$, $p = 0.3$).

Figure 1. Number of larvae counted per plant, one day after larvae were placed on mimosa plants. Plants had either no predators excluded (control) or ants, birds, or both excluded. Raw data points (♦) are staggered on the x-axis so all data points can be shown, and horizontal bars show the mean for each treatment.

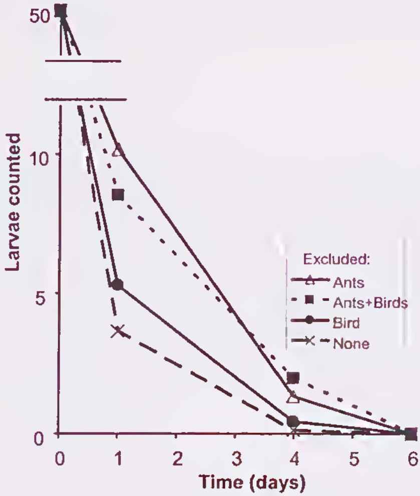

Figure 2. Number of larvae counted per plant, over time, after 50 larvae were placed on each plant at day 0. Plants had either ants (Δ), birds (●), both (■), or no predators excluded (X).

Excluding ants increased the number of larvae found (d.f. = 1, $\chi^2 = 20$, $p < 0.0001$) four days after placing larvae in the field (Figure 2). Excluding birds appeared to slightly affect larval survival (Figure 2), although this was not significant (d.f. = 1, $\chi^2 = 2.9$, $p = 0.08$). There was no important interaction between excluding birds and excluding ants (d.f. = 1, $\chi^2 = 0.9$, $p = 0.3$). Numbers of larvae observed decreased over time, with more larvae observed on plants with ants excluded (Figure 2). No larvae were observed on day 6.

Overall, few larvae were found, and ants were observed disturbing larvae, which then descended to the ground on a silk thread. There were differences between observers (d.f. = 1, $\chi^2 = 4.4$, $p = 0.03$), which suggests that the larval counting process may not have been perfect and not all larvae present were counted. Only one larva was found caught in the sticky gel and 21 prepupae were found; 12 in the ant-excluded plants, and 9 in plants that had ants and birds excluded.

The ants collected were *Polyrhachis crawleyi*, *P. schenkii*, *P.* sp. nr *obtusa*, *Rhytidoponera* sp. nr *aurata*, *Odontomachus* sp. nr *turneri*, *Crematogaster* sp. (*C. laeviceps* group) and *Ochetellus* sp. Very little is known about the ecology of these species, but all ants appear to be generalist scavengers rather than specialised predators (A. Andersen, pers. comm.). Within two days of excluding ants, plants had obvious large, sticky globules exuding from the extrafloral nectaries at the base of each leaf.

Crimson Finches *Neochmia phaeton* were observed near the mimosa plants, and twice were found trapped inside the bird nets; these are however primarily seed-feeders (Todd *et al.* 2003). The only insectivorous birds observed in the area were Rainbow Bee-eaters *Merops ornatus*.

Discussion

Ants commonly disturbed macaria larvae, and either removed them or caused them to drop on silk threads. Birds had an effect on larval numbers, but this was not as important as the effect of ants.

Low numbers of larvae were found after release. It is possible that many larvae were present in the foliage but not found. The cryptic colour of the larvae and differences in larvae counted on the same plants between observers suggests this is likely. Many larvae probably also pupated within several days of being placed on plants.

Ant species found on mimosa were generalists. Given that large sticky globules were observed at the base of the leaves when ants were excluded, we can conclude thar ants feed from these extrafloral nectaries. It is likely that mimosa evolved these nectaries to attract such ants, which then deter herbivores, as is common in the Mimosaceae outside of Australian rangelands (Norris *et al.* 1994); these associations appear to be common in the native range of mimosa. Of the leguminous plants studied in Mexico, 73% had close associations with ants, and use of extrafloral nectaries was the most common ant-plant interaction in the native range of mimosa (Rico-Gray *et al.* 1998). This association with a range of ants that deter herbivores may be one reason why mimosa has become such a 'successful' weed.

The sticky gel may have also deterred other predators such as spiders, frogs and lizards. Being a wetland, the area has an abundance of frogs, such as *Litoria bicolor*, which commonly sits on mimosa branches (pers. obs.). These other predators were not investigated in this study, but none were observed caught in the gel.

Overall, only a small proportion of all larvae placed on mimosa plants were seen. Larvae used in this experiment were late instar, so many may have dropped to the ground to pupate during the trial. Larvae are also cryptic, and some may have been missed while counting.

When this experiment was conducted, macaria had not been recovered from any site where it had been released. Recent surveys, however, have found that it has established and spread widely on mimosa in the Northen Territory (B. Routley, unpubl.). Although predators such as ants and birds do remove and disturb a considerable proportion of larvae, macaria is still capable of surviving and spreading. This may be due in part to the insect's high fecundity (Heard *et al.* 2001), or because the density of mimosa thickets would allow larvae to simply drop onto a lower branch if disturbed. The effect predators have on population density is still unknown. This

paper shows that predators can remove considerable numbers of larvae, although this does not necessarily prevent insects from colonising new areas.

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Threatened fishes of the Northern Territory

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Abstract

Fifty species of Northern Territory fishes have threatened species status according to several Acts and organisations. Almost half of these species (26) are elasmobranchs, of which 11 are whaler sharks (family Carcharhinidae). Nine other listed species are syngnathids (seahorses and pipefishes), which are speciose in the Northern Territory. Most of the different threatened species listings assign different levels of threat, although the two speartooth sharks, the Finke desert-goby, the four sawfish and the Angalarri grunter all share quite similar listings between the ASFB, EPBC and PWCNT. The poor state of knowledge of the Territory's fish populations has hindered the assessment processes.

Introduction

The Northern Territory has a diverse but not well-known fish fauna, occurring in desert waterholes to mangrove creeks and offshore over the continental shelf. About 1300 fish species are known from the Northern Territory (NT), a number of which are undescribed (H. Larson, in prep.). New fish species are still turning up in Darwin Harbour (e.g. Larson and Takita 2004), and a long-term study of coral reefs of the Cobourg Peninsula Marine Park is revealing many more fish records (V. Gomelyuk videotapes). There are few recent publications which summarise portions of the NT fish fauna, examples being Taylor's 1964 *Fishes of Arnhem Land* (the results of a 1948 American - Australian scientific expedition to eastern Arnhem Land), Larson and Martin's 1990 *Freshwater Fishes of the Northern Territory* and Larson and Williams' 1997 checklist of Darwin Harbour fishes.

The fish fauna is still not fully documented, and the status of the fish populations themselves is even less well-known, with the exception of some commercially important species such as Barramundi *Lates calcarifer* and Spanish Mackerel *Scomberoides commersonianus*. The first conservation listing of NT fishes was in Harris (1985) (the proceedings of the Australian Society for Fish Biology's (ASFB) first conference on Australian threatened fishes). This included only two NT species: the Exquisite Rainbowfish *Melanotaenia exquisita* and Midgley's Grunter *Pingalla midgleyi*, which were both listed as having restricted distributions. Provided below are the various national and international species listings and some comments on the present status of NT fish species.

Remarks

Since Harris' listing, additional research has added to our knowledge of NT fish distributions and the number of threatened species. Northern Territory threatened fish are now listed by the Australian Society for Fish Biology's Threatened Fish Committee (ASFB 2003), the International Union for the Conservation of Nature's Red List of Threatened Species 2003 (IUCN; http://www.redlist.org/), Pogonoski *et al.* (2002), the Commonwealth Government (under the *Environment Protection and Biodiversity Conservation Act 1999*) and the Parks and Wildlife Commission of the NT (PWCNT 2002; also online). All NT species with a threatened status under any of these bodies are shown in Table 1 (these are currently under review). The IUCN and ASFB list the greatest number of threatened NT species. Out of the total of 50 listed species, IUCN lists 49 and ASFB lists 38 species. They both agree that 14 of these (mostly marine) species are Data Deficient.

The EPBC Act protects fauna by listing species and communities within Commonwealth areas as well as protected (conservation) areas and is triggered by certain actions (e.g. a development proposal for an area inhabited by listed species). Listed fishes are afforded protection within Commonwealth waters, while the NT has its own legislation designed to protect fauna.

Pogonoski *et al.*'s (2002) "Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes" was simultaneously published in softcover and on the Environment Australia website in February 2002 (http://www.deh.gov.au/coasts/species/marine-fish/index.html). Pogonoski *et al.* (2002) includes an overview in some detail of the conservation status of 114 species of marine and estuarine fishes and incorporates information provided by the ASFB threatened fish committee as well as the results of a specialist workshop on Australian threatened fish populations.

Under the *Territory Parks and Wildlife Act 2000*, the PWCNT produced a list of threatened fauna of the NT, which included nine threatened fish species (three endangered and six vulnerable), in addition to listing 188 species as Near Threatened, Least Concern or Data Deficient (PWCNT 2002). The PWCNT list of threatened species is not always congruent with IUCN, EPBC or ASFB listings (Table 1). For example, the Freshwater Tongue Sole *Cynoglossus heterolepis* is an estuarine to freshwater species known from the Adelaide River to the East Alligator River and southern New Guinea (Allen 2001), that is not endangered or threatened, but was apparently listed by the PWCNT based on information in Allen *et al.* (2002). The main consensus between the ASFB, EPBC and PWCNT listings seems to be the two species of speartooth sharks *Glyphis* sp. A and sp. C, Finke Desert-goby *Chlamydogobius japalpa*, Grey Nurse Shark *Carcharias taurus*, the four sawfish *Pristis* and *Anoxypristis,* and the Angalarri Grunter *Scortum neili*. The PWCNT's *Strategy for the Conservation of Threatened Species and Ecological Communities in the Northern Territory of Australia* is a management tool for dealing with threatened taxa, but it does not mention aquatic species or fish.

Table 1. Fish species of conservation significance in the NT. IUCN = 2002 IUCN Red List of Threatenened Species; EPBC = Environmental Protection and Biodiversity Conservation Act 1999; COAP = Pogonoski *et al.* (2002); ASFB = Australian Society for Fish Biology (2003); PWCNT = Parks and Wildlife Commission of the NT. CE = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Lower Risk (Near Threatened), LC = Lower Risk (Least Concern), LR = Lower Risk (Conservation Dependent), DD = Data Deficient. Species listed as Data Deficient by PWCNT (2002), but not elsewhere, are not included.

Species	IUCN	EPBC	COAP	ASFB	PWCNT
Ariidae					
Cinetodus froggatti Small-mouthed Catfish	DD	-	-	DD	-
Atherinidae					
Craterocephalus centralis Finke River Hardyhead	NT	-	-	NT	-
Carcharhinidae					
Carcharhinus amblyrhynchos Grey Reef Shark	NT	-	LC	-	-
C. brevipinna Spinner Shark	NT	-	LC	-	-
C. falciformis Silky Shark	LC	-	LC	-	-
C. leucas Bull Shark	NT	-	LC	-	-
C. limbatus Blacktip Shark	NT	-	DD	DD	-
C. obscurus Dusky Shark	NT	-	NT	NT	-
C. plumbeus Sandbar Shark	NT	-	NT	NT	-
Galeocerdo cuvier Tiger Shark	NT	-	LC	-	-
Glyphis sp. A Speartooth Shark	CE	CE	CR	CE	EN
G. sp. C Northern River Shark	CE	EN	EN	EN	EN
Triaenodon obesus Reef White-tip	NT	-	LC	-	-
Cynoglossidae					
Cynoglossus heterolepis Freshwater Tongue Sole	-	-	-	-	EN
Dasyatidae					
Himantura chaophraya Freshwater Whipray	VU	-	VU	VU	DD
Taeniura lymma Blue-spotted Fantail Ray	NT	-	LC	NT	-
Urogymnus asperrimus Porcupine Ray	VU	-	NT	NT	-
Eleotridae					
Hypseleotris sp. Katherine River Gudgeon	DD	-	-	DD	-
Engraulidae					
Thryssa scratchleyi Freshwater Anchovy	DD	-	-	DD	-
Gobiidae					
Chlamydogobius japalpa Finke Desert-goby	VU	-	-	VU	VU
Silhouettea hoesei Hoese's Silhouette Goby	DD	-	-	DD	-
Mobulidae					
Manta birostris Manta Ray	DD	-	LC	-	-

continued on next page

Table 1 continued

Species	IUCN	EPBC	COAP	ASFB	PWCNT
Myliobatidae					
Aetobatus narinari White-Spotted Eagle Ray	DD	-	LC	-	-
Odontaspidae					
Carcharias taurus Grey Nurse Shark	VU	CE (E coast)	EN	EN	DD
Orectolobidae					
Orectolobus ornatus Banded Wobbegong	LC	-	DD	DD	-
Pristidae					
Pristis microdon Freshwater Sawfish	CR	VU	-	CE	DD
P. clavata Dwarf Sawfish	EN	-	-	EN	VU
P. zijsron Green Sawfish	EN	-	-	EN	VU
Anoxypristis cuspidata Narrow Sawfish	VU	-	-	VU	VU
Rhincodontidae					
Rhincodon typus Whale Shark	VU	VU	DD	DD	-
Rhinidae					
Rhynchobatus australiae White-Spotted Shovel-Nose Ray	VU	-	LC	-	-
Serranidae					
Cromileptes altivelis Barramundi Cod	LR	-	-	LR	-
Epinephelus lanceolatus Queensland Grouper	LR	-	-	LR	-
E. coioides Estuary Rockcod	LC	-	-	LC	-
E. fuscoguttatus Flowery Rockcod	LC	-	-	LC	-
E. malabaricus Malabar Grouper	LC	-	-	LC	-
Sphyrnidae					
Sphryna lewini Scalloped Hammerhead	NT	-	LC	-	-
S. mokarran Great Hammerhead	DD	-	LC	-	-
Syngnathidae					
Doryrhamphus dactyliophorus Banded Pipefish	LC	-	-	LC	-
Hippichthys parvicarinatus Estuary Pipefish	LC	-	-	LC	-
Hippocampus alatus Winged Seahorse	DD	-	DD	DD	-
H. dahli Low-Crowned Seahorse	NT	-	-	NT	-
H. multispinus Northern Spiny Seahorse	DD	-	DD	DD	-
H. taeniopterus Yellow Seahorse	DD	-	DD	DD	-
Solegnathus hardwickii Pallid Pipehorse	DD	-	-	DD	-
S. lettiensis Gunther's Pipehorse	DD	-	-	DD	-
Syngnathoides biaculeatus Alligator Pipefish	DD	-	-	DD	-
Terapontidae					
Pingalla lorentzi Lorentz' Grunter	-	-	-	-	VU
P. midgleyi Midgley's Grunter	NT	-	-	NT	-
Scortum neili Angalarri Grunter	NT	-	-	NT	VU
Xiphiidae					
Xiphias gladius Broadbill Swordfish	DD	-	DD	DD	-

The seahorses, genus *Hippocampus* (Table 1), are all IUCN Red-listed (one species listed as Endangered, 20 Vulnerable and 11 Data Deficient). In addition, there is considerable confusion over the correct names for each species. No revision of the whole genus has yet been carried out, although Kuiter (2001) attempted to identify and name the Australian species. There are 33 *Hippocampus* species presently listed by the IUCN. Five seahorse species occur in the NT, but none of the names currently used for the NT species appear on the IUCN list, due to the nomenclatural confusion. The species are concealed and confused with other names on the list, and the three recently described NT species (Kuiter 2001) do not appear on the IUCN list. Work is continuing on *Hippocampus* species by Sara Lourie of McGill University, and it is hoped that this charismatic group of fishes will soon be better understood.

Of the 51 species listed in Table 1, 26 are elasmobranchs (sharks, rays and sawfish). These large and often slow-growing fishes have been recognised as being highly vulnerable to fishing as a threatening process, either as bycatch or as target species (Pogonoski *et al.* 2002). Some of these are large and charismatic; for example the Freshwater Sawfish *Pristis microdon*, which reaches about 4.6 m (Allen *et al.* 2002), and is Australia's largest freshwater fish, famous for waiting out the dry season in remote areas in small waterholes. Of the listed elasmobranchs, 11 belong to the family Carcharhinidae (whaler sharks). This family includes not only the speartooth sharks (*Glyphis* sp. A and C) and the Tiger Shark *Galeocerdo cuvieri*, but also the various blacktip and grey whalers which are taken commercially in NT waters. In recent years there has been considerable effort expended to determine the status of various elasmobranch populations, resulting in a number of species receiving IUCN Red List status.

The undescribed *Glyphis* species are both listed as Critically Endangered by the IUCN (2002), and as Endangered under the Territory Parks and Wildlife Conservation Act 2000, but no NT management program is in preparation (PWCNT 2002). A national Recovery Plan for *Glyphis* is currently being drafted. *Glyphis* sp. A and *Glyphis* sp. C are known to inhabit several rivers in the NT, but their exact distributions and population numbers are not known. Museum and Art Gallery of the Northern Territory records and sight records of visiting researcher Tim Berra (in litt.) indicate that juvenile *Glyphis* sp. C may be common in the Adelaide River.

The 25 non-elasmobranch Near-Threatened category fish in Table 1 are mostly commercially significant (e.g. groupers, rock cods), syngnathids (seahorses and pipefishes) or small freshwater species (e.g. grunters). Some freshwater fish have very restricted distributions, making them vulnerable to changes in water quality, flow, condition or competition from introduced species. For example, the Finke River Hardyhead *Craterocephalus centralis* and the Finke Desert-goby *Chlamydogobius japalpa* are known only from the Finke River system in central Australia, and the hardyhead is the only species of the genus in that system. Both these species are highly vulnerable to the potential effects of any introduced species (which have been found in waterways not far from the Finke system), such as *Gambusia holbrooki* (the inappropriately-named mosquitofish) recently removed from Ilparpa Swamp and the Murray Cod

Maccullochella peeli recently found to be illegally introduced into Policeman Waterhole in the Davenport Ranges. The NT has been fortunate so far in that most occurrences of introduced exotic or noxious fish species have been dealt with successfully or otherwise contained (e.g. the removal of Jewel Cichlids *Hemichromis bimaculatus*, from Ludmilla Creek at Fannie Bay) and that Northern Territory Fisheries has an active aquatic pest team to deal with such outbreaks.

Terrestrial parks and reserves within the NT provide some protection to threatened fish species, as do the few marine protected areas. There are only three of the latter: two small Aquatic Life Reserves in Darwin Harbour (at Doctors' Gully and East Point) and one large Marine Park (Garig Gunak Barlu National Park, previously known as Cobourg Marine Park). The Commonwealth-administered Kakadu National Park includes several major river estuaries and islands as well as a range of freshwater habitats. Taking of fish (by hook and line) is permitted in the National Parks, but not in the Aquatic Life Reserves.

The Northern Territory *Fisheries Act 1988* is intended for the management and conservation of marine fishes, utilising Fisheries Management Plans to "conserve, enhance, protect, utilise, and manage the fisheries of the Territory". So far, fish species in the NT are only protected by bag limits on several species, commercial fishing closures and the difficulty of access to many habitats. No species are wholly protected under NT legislation other than groupers of the genus *Epinephelus* larger than 1.2 m long (this protects adult females of the Giant Grouper *Epinephelus lanceolatus*).

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The Northern River Shark *Glyphis* sp. C occurs in several Top End rivers and is thought to be Endangered, perhaps critically so. (Helen Larson)

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A survey of nocturnal reptiles of Robin Falls, Northern Territory: implications of *Bufo marinus*

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Abstract

Twenty-two species of nocturnal reptiles were identified in the Robin Falls area during one year (2001-02) of regular observational surveys. More reptiles were observed during the build-up and early dry season compared to the wet and the dry seasons. The greatest number of individuals (42) and species (15) of nocturnal reptiles were recorded during the build-up (Sept.-Nov.), during which average night-time temperatures of 28°C, absolute humidity of 19.07g/m^3, and total rainfall of 190 mm were experienced. While comparisons of seasonal climatic factors produced trends, temperature, humidity and rainfall did not show any significant relationship with the number of observed reptiles. Nearly one third of the nocturnal reptile species listed in the Robin Falls area are considered to be susceptible to the Cane Toad *Bufo marinus*. This study provides preliminary quantitative baseline data from which to examine any future detrimental effects of the Cane Toad on nocturnal species of reptiles in the Robin Falls area.

Introduction

Robin Falls is a small tourist haven, located near the Adelaide River Township, which lies about 120 km south of Darwin in the Northern Territory (NT). The falls are reached via Dorat Road, which turns off the Stuart Highway near the Adelaide River Township. A 15-minute walk from the Robin Falls car park leads along a creek edged with monsoon forest. The creek originates from a spring above the escarpment and carves its way through swamp and open woodland until it clears the edge of the plateau and plunges into a large rock basin in the valley below. After the valley, the creek passes underneath Dorat Road and heads towards lower floodplains. Dorat Road travels through plateau and lowland wetland and over many tributaries similar to that of Robin Falls, all of which feed into the Adelaide River. Plant communities present in this region include woodland, monsoon forest, swampland and floodplain.

Robin Falls is privately owned, but graciously opened to visitors, and managed by the Landcare Council NT and other community groups such as Coomalie Water Watch and Greening Australia. There is little evidence of disturbance in the area except for a few small cleared areas for camping sites, a short gravel access road and a narrow

500 m walking track leading to the falls, and little invasion by weedy plant species. In recent years, fires have occurred every 1–2 years (fire events noted in 2000 and 2001). Dorat Road passes many privately owned properties that show little evidence of development. There is a banana plantation not far from the Adelaide River Township but most properties appear unaltered, with little (generally pastoral) or no land use.

A compilation of nocturnal species of reptile that have been identified (during 1911–2002) in the Robin Falls area is available from the Biological Records Scheme (BRS), set up by the Parks and Wildlife Commission of the Northern Territory (PWCNT). However, comprehensive scientific research, such as long-term ecological studies, is lacking in this area. This is unfortunate given that the Cane Toad *Bufo marinus* is slowly progressing towards Darwin. Cane Toads were introduced into Queensland in 1935 to act as a biological control for the beetle *Dermolepia albohirtum*, which is a pest in sugar cane crops (Straughan 1966). While ineffective at controlling the cane beetle, the Cane Toad has effectively invaded much of the north-eastern coast and hinterland of Australia. The toads possess large, paired parotid glands located dorsally on the neck, which produce a cocktail of toxic chemicals including biogenic amines and hallucinogenic compounds such as the bufogenins (Sutherland 1983, Edstrom 1992). The Australian native fauna have not co-evolved with these types of toxins, and anecdotal observations of species declines within areas of toad invasion and recent studies demonstrate that many Australian predators are adversely susceptible to these compounds (Covacevich & Archer 1975, Catling *et al.* 1999, van Dam *et al.* 2002). Currently, efforts are being made to conserve local species, such as the Quoll Recovery Plan under the Island Arks Project, which aims to provide safe havens, free from the impacts of exotic species, for native species (B. Rankmore pers. comm.). At the time of this research there had been no records of *B. marinus* in the Robin Falls area (Frogwatch 2004).

Dorat Road leading to Robin Falls is well known among Australian herpetologists for its reptile diversity. During one year of regular surveys in the Robin Falls area, we recorded observations of all nocturnal species of reptile. In this paper, we summarise the number of reptiles and species observed by season, and present an analysis of the relationship between the weather conditions and the number of nocturnal reptile species observed in each season. A preliminary list of nocturnal reptiles in the Robin Falls area is also presented, indicating which local species may be impacted by the Cane Toad.

Methods

Visual encounter surveys (VES) were conducted along line transects between 21:00 and 24:00 hours every 10 days from December 2001 to November 2002 (Crump & Scott 1994). Surveys were conducted on two transects: Dorat Road and Robin Falls (13º 21' 20"S, 131º 07' 17"E).

Dorat Road: the first transect was conducted along 15 km of bitumen road, starting from the Adelaide River township turnoff and ending at the Robin Falls turnoff. Reptiles were located from a car using headlamps and car headlights. The car traveled on average 40 km/hr, while the road and road shoulders were searched for reptiles.

Robin Falls: the second transect used the 500 m long walking track that begins at the Robin Falls car park and ends at the falls. Reptiles were searched for on foot using headlamps. Walking pace was slow, and 2 m on either side of the walking track were searched.

The VES were conducted at a consistent pace, and the focal area surveyed was within the predetermined radius to the left, front and right of the observer. The surveys did not involve shifting leaf litter or lifting and turning rocks and logs, thus allowing us to minimise habitat disturbance, to eliminate the risk of injury to the animal and observer from improper handling of animals, and to comply with the legal guidelines of the Parks and Wildlife Commission of the Northern Territory (PWCNT) (it is a criminal offence to handle native wildlife unless holding a PWCNT permit). All nocturnal species of reptile encountered were recorded (amphibians were not included in this study because they are a focus of a separate paper). Air temperature (°C) and relative humidity (%) were measured using a hand held meter (HM34C Vaisala), and rainfall was measured by a rain gauge.

Analysis

Four recognized seasons were used to compare species numbers; build-up (Sept.-Nov.); wet (Dec.-Feb.); early dry (Mar.-May); and dry (Jun.-Jul.). Results were collated to show the number of each species of nocturnal reptile found in each season, and statistically compared using ANOVA (Systat, SAS). Climatic variables and the numbers of species identified are presented graphically and correlated statistically using logarithmic regression, for poisson distributed count data (Systat, SAS). Since humidity is dependent on air temperature (Ta), for the purpose of statistical analyses relative humidity was converted to absolute humidity (AH) (g/m^3) using the Smithsonian water density table at the given ambient temperature (List 1971). The level of significance for all analyses was set at $p < 0.05$.

The list of reptile species that may be found in the Robin Falls area was compiled using information from Wilson and Swan (2003) on the geographical distribution of reptiles and from species listed in the BRS (1911-2002).

Results

Nocturnal species of reptiles observed in the Robin Falls area

Table 1 provides a summary of the names and numbers of each species encountered on line transects in the Robin Falls area each season. A total of 22 nocturnal reptile

species were recorded during one year of surveys (36 surveys). The Freshwater Crocodile *Crocodylus johnstoni*, was encountered along Anniversary Creek (a tributary crossed by Dorat Road); however, the species was excluded from any analysis because the tributary was not consistently surveyed for this species throughout the survey period.

Table 1. A list of the species and total numbers of each of the reptiles observed on Dorat Road and Robin Falls transects, summarised by season.

Species	Wet (Dec.-Feb.)	Early dry (Mar.-May)	Dry (Jun.-Aug.)	Build-up (Sept.-Nov.)
Gekkonidae				
Gehyra australis	3	1	2	4
Heteronotia binoei				2
Oedura marmorata				1
Strophurus ciliaris ciliaris		1	4	1
Pygopodidae				
Delma tincta	1			
Lialis burtonis		3		5
Pythonidae				
Antaresia childreni		4	1	3
Liasis mackloti	1			
Liasis olivaceus			1	3
Morelia spilota		1		
Acrochordidae				
Acrochordus arafurae		15		
Colubridae				
Boiga irregularis	1			2
Stegonotus cucullatus				1
Tropidonophis mairii		1		2
Elapidae				
Acanthophis praelongus				13
Brachyurhophis roperi	1			
Furina ornata	1	1	2	1
Pseudechis australis		1		2
Pseudonaja nuchalis		1		
Rhinoplocephalus pallidiceps				1
Suta punctata				1
Vermicella intermedia		1		
Number of species	6	11	5	15
Total number of reptiles	8	30	10	42

Comparisons between season and number of observed nocturnal reptiles

The numbers of nocturnal reptiles observed in each season were significantly different (ANOVA: $F_{3,32} = 9.538$; $p < 0.001$). The greatest number of reptiles (42) and number of species (15) were found during the build-up (Sept.-Nov.) (Table 1). The number of species identified during the build-up included over half of the total species (22) observed during the one year of surveys. The number of individuals encountered during the early dry was also high (30), but was dominated by a large number (15) of Arafura File Snakes *Acrochordus arafurae* found in Anniversary Creek. Despite the predominance of file snakes, the number of species observed during the early dry (11) included half the total number of species encountered during the entire survey period. Fisher's PLSD post-hoc tests (5% significance level) found no statistical difference between reptiles observed during the build-up and the early dry ($p = 0.1190$). The lowest numbers of reptiles were observed during the wet (8) and the dry (10) seasons, which were not significantly different (Fisher's post-hoc: $p = 0.7912$) between seasons. Despite the low numbers of animals observed during the wet, two species, the Northern Shovel-nosed Snake *Brachyurhophis roperi* and the Black-necked Legless Lizard *Delma tincta,* were encountered during this season only.

Results from analyses of variance found significant seasonal differences in all climatic factors (ANOVA Ta: $F_{3,32} = 20.834$, $p < 0.001$; AH: $F_{3,32} = 71.491$, $p < 0.001$; Rain: $F_{3,32} = 5.486$, $p < 0.004$). Night-time air temperature and absolute humidity were statistically higher in the wet, early dry and build-up than in the dry (Fisher's post-hoc: $p < 0.0001$) (Figure 1). While the wet season had similar average temperature and humidity to that of the build-up and early dry, total rainfall (816 mm) was greater than all other seasons (Fisher's post-hoc $p < 0.0033$) (Figure 1).

Statistical correlations between climatic variables and the number of observed reptiles

All climatic variables were log transformed to minimise variation either side of the mean and fit assumptions of the analyses. A correlation matrix (StatView, SAS) produced small positive relationships between reptile counts and log temperature and log absolute humidity (maximum R^2 value 0.315). Further analysis, using logarithmic regression of poisson distributed reptile count data, found no statistically significant ($p > 0.05$) relationship between the number of reptiles and climatic variables (Table 2). The statistical correlation between reptile number and log rainfall was not significant ($R^2 = 0.027$) and therefore was not included in the regression model.

While no significant statistical correlations were found between climatic factors and the numbers of reptiles found in each season, trends are evident when the number of species observed in each season is considered along with the plot of the climatic variables for each season (Figure 1). The highest numbers of reptiles were found during warm, humid conditions, and the lowest numbers were found in the coolest, driest season.

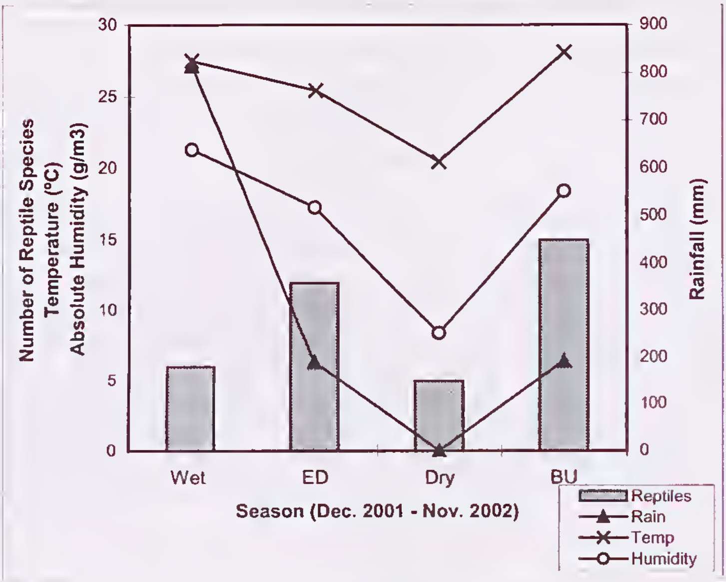

Figure 1. The number of nocturnal reptile species identified in each season and associated climatic variables (ED = early dry; BU = build-up).

Table 2. Reptile counts and climatic variables correlated using logarithmic regression (StatView, SAS). Predictor variables were log transformed, n = 36.

	Coefficient	Standard error	Standard coefficient	R^2	F-Value	p-Value
log temperature	12.790	7.065	0.297	0.088	3.277	0.0791
log humidity	4.394	2.288	0.313	0.098	3.689	0.0632

A list of reptile species in the Robin Falls area

A list of nocturnal species of reptiles reported to inhabit the Robin Falls area is presented in Table 3 (Wilson & Swan 2003, BRS, PWCNT). Half of the nocturnal reptile species (22 of 44) were recorded during one year of regular surveys (asterisks in Table 3). At least 50% of species within most families were recorded on Dorat Road and/or at Robin Falls. Most species of the Elapidae and Pythonidae were recorded (except for the Black-headed Python) but no species of Blind Snake (Typhlopidae) were identified, which is not unusual given their burrowing behaviour (Cogger 2000).

Cane Toad toxins are considered life-threatening to a number of the listed reptiles (Table 3), based on information provided on diet (Wilson & Swan 2003), studies on the effects of toxins on some species of snake (Covacevich & Archer 1975, Phillips *et al.* 2003) and an impact assessment report (van Dam *et al.* 2002). Nearly one third (30%) of nocturnal species of reptile are considered susceptible to the Cane Toad. Only two out of the total species listed are known to be tolerant of *Bufo* toxins: the Keelback Snake *Tropidonophis mairii* and the Slaty-grey Snake *Stegonotus cucullatus* (Ingram & Covacevich 1990, Phillips *et al.* 2003). All other reptiles listed do not appear to prey on amphibians.

Discussion

During this study, 22 species of nocturnal reptiles were identified near Robin Falls. Most species (15) were encountered during the build-up when humidity and temperature were highest. The number of species observed during the early dry was similarly high (11), though there were differences in the types of species encountered. While reptile numbers were much lower in both the wet and dry seasons, field surveys resulted in two additional species (Northern Shovel-nosed Snake and *D. tincta*) being observed in the wet season. Thus, the build-up provides the best opportunity to see nocturnal species of reptiles, but season influences the type of species that may be encountered. As an additional example, the high densities of Arafura File Snakes *A. arafurae* found in Anniversary Creek during the early dry may be predicted following the heavy rains of the wet season because this species is aquatic and inhabits freshwater streams wherever monsoonal floods occur (Cogger 2000).

Based solely on the one year of survey data, we were unable to statistically correlate the climatic conditions of the seasons with the number of reptiles; however there was a clear trend of the greatest numbers of reptiles and species being found in warm, humid seasons and the lowest numbers in the coolest, driest season. Consideration of the physiological requirements of reptiles may provide some explanation of this trend. Reptilian physiology is temperature dependent, and warmer temperatures allow reptiles to metabolise food more quickly for nutrient and water acquisition (Bennett 1982, Andrews & Pough 1985). Many species of reptile limit their activity during the dry season to balance energy requirements and water relationships during less favourable climatic conditions (Christian & Green 1994, Christian & Griffiths 1996, Christian *et al.* 1999). Therefore, the high night-time temperatures and humidity of the wet, build-up and early dry would seem ideal for nocturnal reptilian activity, and the cooler, drier conditions of the dry would be expected to decrease activity and consequently the number of animals observed. In this study, the trend in the numbers of reptiles observed across the seasons supports expectations based on the physiological requirements of reptiles, except during the wet season.

Table 3. Nocturnal reptile species expected to be found in the Robin Falls area (Wilson & Swan 2003, Biological Records Scheme, PWCNT), * introduced species; *** recorded in this study; SCT species susceptible to the Cane Toad (van Dam *et al.* 2002) indicated with an 'x'.

Scientific name	Recorded this study	Common name	SCT
Crocodylidae			
Crocodylus johnstoni	***	Freshwater Crocodile	x
Crocodylus porosus		Saltwater Crocodile	
Chelidae			
Chelodina rugosa		Northern Long-necked Turtle	x
Elseya dentata		Northern Snapping Turtle	
Gekkonidae			
Diplodactylus conspicillatus		Fat-tailed Gecko	
Diplodactylus stenodactylus		Sand-plain Gecko	
Gehyra australis	***	Northern Dtella	
Gehyra nana		Spotted Rock Dtella	
Hemidactylus frenatus *		Asian House Gecko	
Heteronotia binoei	***	Bynoe's Gecko	
Heteronotia planiceps		Northern Cave Gecko	
Nephrurus sheai		Northern Knob-tailed Gecko	
Oedura marmorata	***	Marbled Velvet Gecko	
Oedura rhombifer		Zigzag Velvet Gecko	
Strophurus ciliaris ciliaris	***	Northern Spiny-tailed Gecko	
Pygopodidae			
Delma borea		Northern Snake-lizard	
Delma tincta	***	Black-necked Legless Lizard	
Lialis burtonis	***	Burton's Snake-lizard	
Pygopus steelescotti		Northern Hooded Scaly-foot	
Pygopus nigriceps		Black-headed Scaly-foot	
Typhlopidae			
Ramphotyphlops diversus		Northern Blind Snake	
Ramphotyphlops guentheri		Top End Blind Snake	
Ramphotyphlops ligatus		Robust Blind Snake	
Ramphotyphlops tovelli		Darwin Blind Snake	
Ramphotyphlops unguirostris		Claw-snouted Blind Snake	
Pythonidae			
Antaresia childreni	***	Children's Python	x
Aspidites melanocephalus		Black-headed Python	x
Liasis mackloti	***	Water Python	x
Liasis olivaceus	***	Olive Python	x
Morelia spilota	***	Carpet Python	x
Acrochordidae			
Acrochordus arafurae	***	Arafura File Snake	

Table 3 continued

Scientific name	Recorded this study	Common name	SCT
Colubridae			
Boiga irregularis	***	Brown Tree Snake	x
Enhydris polylepis		Macleay's Water Snake	x
Stegonotus cucullatus	***	Slaty-grey Snake	
Tropidonophis mairii	***	Keelback Snake	
Elapidae			
Acanthophis praelongus	***	Northern Death Adder	x
Brachyurhophis roperi	***	Northern Shovel-nosed Snake	
Rhinoplocephalus pallidiceps	***	Northern Small-eyed Snake	x
Furina ornata	***	Orange-naped Snake	
Pseudechis australis	***	King Brown Snake	x
Pseudonaja nuchalis	***	Western Brown Snake	x
Suta punctata	***	Little Spotted Snake	
Vermicella intermedia	***	Wide-banded Bandy-bandy	
Vermicella multifasciata		Narrow-banded Northern Bandy-bandy	

The significantly higher rainfall during the wet season is an additional factor to consider when attempting to understand the observed trends in reptile numbers associated with climatic variables. The quantity of rain itself is not likely to be the key, but rather the amenable environmental conditions created by excess surface water. The conundrum from this study is that fewer reptiles were observed during the wet season when it would be expected that food resources, such as frogs, would be plentiful. A study on the movements of Water Pythons, Keelbacks and Slaty-grey Snakes at Fogg Dam near Darwin had similar findings in which adults of these species were encountered less often during the wet season than in the dry season (Brown *et al.* 2002). The low density of adult Water Pythons encountered was explained by the migration of their prey, Dusky Rats *Rattus colletti*, which disperse over the floodplain during the wet season. Similarly, in this study, the Northern Death Adder *Acanthophis praelongus* were most commonly encountered along the Robin Falls walking track during the build-up when frog densities were at their highest along the creek, but were not encountered during the wet season when frog densities were at their lowest (McArthur & Young unpubl.). For frogs, it is assumed that the creek provides a permanent water refuge during the dry and build-up, and that the floodplain provides suitable breeding areas during the wet. Therefore, we suspect that Northern Death Adders disperse from the creek to the floodplains during the wet to follow their prey (frogs), as do water pythons (Brown *et al.* 2002). Thus, while counts of reptiles were low during the wet season, it may not be indicative of inactivity but instead an artifact resulting from the seasonal dynamics of the floodplain.

The advantage of choosing two different transects to conduct counts (road and walking track) is that the diversity of habitats sampled is increased and thus the diversity of reptile species encountered is similarly increased. The Brown Tree Snake (or more aptly named the 'Night Tiger') *Boiga irregularis*, and the Carpet Python *Morelia spilota*, were only encountered on the Robin Falls transect. The methods used for each transect were different and, therefore, any analysis directly comparing the number of reptiles encountered per distance between transects would be misleading. Nonetheless, it is worth noting that during the build-up the Robin Falls transect provided more individuals per distance than the Dorat Road transect (2.6 reptiles/km versus 0.22 reptiles/km, respectively). The difference in habitats (inland monsoon forest with permanent water versus dry floodplain) will likely influence the diversity of reptiles encountered.

Currently, the Cane Toad at all life stages is a concern, either directly or indirectly, for native wildlife in the Top End (Covacevich & Archer 1975, Lawler & Hero 1997, Catling *et al.* 1999, Crossland 2000, van Dam *et al.* 2002, Altman *et al.* 2003). Research on long-term effects of the Cane Toad is lacking; however, based on the knowledge of diet preferences, nearly one third (30%) of the nocturnal species of reptiles local to the Robin Falls area may be susceptible to Cane Toad toxins (Covacevich & Archer 1975, van Dam *et al.* 2002, Wilson and Swan 2003; see also Phillips *et al.* 2003). Some reptile species are generalists, such as the Freshwater Crocodile, and feed on a variety of prey items (including anurans). One study has demonstrated a decline in freshwater crocodile numbers in a 'toad invasion zone' area relative to a 'toad free' area, but the same study also demonstrated persistence of the species within areas where the Cane Toad has a longer history of habitation (Catling *et al.* 1999). Freshwater crocodiles may survive the invasion of the toad given that they either naturally avoid or 'learn' not to select toads as food items. Other species, such as the Northern Death Adder, and the Children's Python *Antaresia childreni*, are considered to be specialists because they feed mainly on frogs, and are more likely to be impacted by the invasion of the Cane Toad. One study has found that the Northern Death Adder need only mouth a Cane Toad to result in death (Covacevich & Archer 1975).

Only two species of reptile are known to be resistant to Cane Toad toxins, the Keelback Snake, and the Slaty-grey Snake (Covacevich & Archer 1975, Phillips *et al.* 2003). The Keelback Snakeis one of only a few native predators able to survive *Bufo* toxins at all life stages: eggs, larvae, metamorphs and adults (Ingram & Covacevich 1990, Altman *et al.* 2003, Wilson & Swan 2003). The tolerance of the Keelback Snake to the Cane Toad is 'attributed to the long evolutionary association of natricines and bufonids' in areas such as North and South America, Asia and Europe, which links it with close relatives in the subfamily Natricinae (Ingram & Covacevich 1990). The future of the other reptiles listed in this study, that are not considered to be susceptible to Cane Toad toxins, will be at less risk because these species specialise on different prey items. For example, the Northern Shovel-nosed Snake consumes only reptile eggs; the Orange-naped Snake *Furina ornata*, eats exclusively skinks; and the two

bandy-bandys, *Vermicella* spp., feed only on blind snakes (*Ramphotyphlops* spp.) (Cogger 2000).

This study has been useful in providing a list of nocturnal reptiles of the Robin Falls area, which denotes in which season animals were found. Twenty-two species of nocturnal reptile were identified and a total of 90 individuals were observed during 36 survey sessions. While this survey of the Robin Falls area provides very preliminary data on the types of nocturnal reptiles and their numbers, it also provides quantitative information that may prove useful given the imminent arrival of the Cane Toad.

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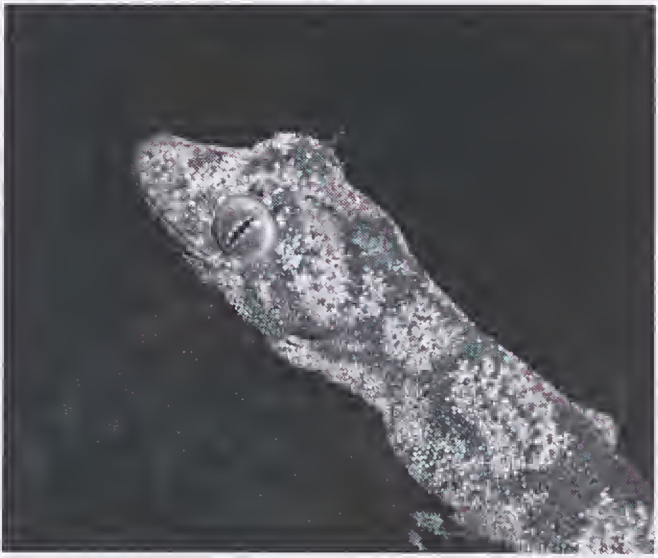

The Northern Spiny-tailed Gecko *Strophurus ciliaris ciliaris* was recorded near Robin Falls mostly in the dry season. (Lorrae McArthur)

The resemblance of Burton's Snake-lizard *Lialis burtonis* to snakes is superficial. (Lorrae McArthur)

The Wide-banded Bandy-bandy *Vermicella intermedia* feeds exclusively on blind snakes and may thus avoid the direct consequences of Cane Toad toxicity. (Lorrae McArthur)

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Distribution and natural history of the cryptic Chameleon Dragon *Chelosania brunnea*: a review of records

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Abstract

The Chameleon Dragon *Chelosania brunnea* is a rarely encountered and poorly-known agamid lizard. A total of 103 records (58 specimen-backed) were collated to examine aspects of its biology. The Chameleon Dragon occurs widely across north and north-western Australia with the majority of records from Kakadu National Park (41% of all records), the Dampier Peninsula, Kimberley and Katherine areas, largely reflecting past wildlife survey effort. Climatic modelling using BIOCLIM predicted its occurrence in extensive areas of the Gulf of Carpentaria and southern Cape York. The Chameleon Dragon is arboreal, apparently sedentary, with almost all records from eucalypt forest and woodland. Breeding is highly seasonal with males observed mostly in May (apparently to select mates) and females recorded mostly in the mid-dry season (July-August) as they descend to dig nest holes. A juvenile has been recorded in January. Hot late dry season wildfires are probably the main threat to Chameleon Dragons. Suggestions are given for further study of this interesting species.

Introduction

The monotypic Chameleon Dragon *Chelosania brunnea* (Gray 1845) is a medium-sized (snout-vent 105 mm), large-headed, short-limbed agamid lizard that is restricted to the wet-dry tropical forests and woodlands of northern Australia (Cogger 1994). The Chameleon Dragon is named because of its superficial similarity to Chameleon Dragons (Family Chameleonidae), to which it is unrelated; a spectacular example of independent covergent evolution. Just two short notes, totalling fewer than 500 words, have been published on the species. Greer (1990) described the Chameleon Dragon as a 'peculiar beast about which little is known'.

Until the 1960s, the distribution of the Chameleon Dragon was reported as Western Australia (Worrell 1963), however this ignored museum specimen records from near Darwin and Arnhem Land, collected in the early 20th century. One of the first published field reports was in 1979, with notes on a significant range extension and behaviour (Husband 1979). After releasing a Chameleon Dragon, Husband (1979)

noted that 'when moving through the branches it was very chameleon-like, slowly almost mechanically moving from point to point…'. A second publication described basic details of reproduction (Pengilley 1982). Miles and Burbidge (1975) and Bush (1985) summarise several additional Western Australian observations.

This paper collates known records of the Chameleon Dragon (to August 2004), develops a predicted distribution by correlative bioclimatic analysis (BIOCLIM) and documents biological details (habitat use, breeding and seasonality) gathered from specimen and unpublished anecdotal records of biologists and field naturalists.

Methods

Data sources

Chameleon Dragon locality records were sought from Australian and international museums, from biological atlas/database schemes managed by Australian state and territory natural resource management departments, and by seeking published and unpublished site records from field biologists and herpetologists (all are listed in acknowledgements or cited in the text). Data sought was locality, georeference, date, habitat and behaviour.

Records with sufficient information on habitat were subjectively classified into five broad habitat types: eucalypt forest, eucalypt woodland, tropical dry forest (= monsoon rainforest), acacia woodland and urban gardens.

Predicting distribution

Known geo-referenced locality records (n = 80), except for the 23 records obtained after a June 1997 cut-off date, were entered into BIOCLIM to predict the distribution of the Chameleon Dragon. BIOCLIM is a bio-climatic analysis and prediction system, which can generate site-specific estimates of monthly temperatures and precipitation for sites anywhere in Australia. Results of this analysis are noted briefly.

Results and discussion

Known distribution

The Chameleon Dragon is widely distributed in Australia's wet-dry tropics across almost six degrees of latitude (12°–17°30S) and 16 degrees of longitude (122°–138° E): a land area of c. 800,000 km^2. The known distribution of the Chameleon Dragon is given in Figure 1. The BIOCLIM-predicted distribution encompassed known records but furthermore predicted occurrence in the Qld Gulf of Carpentaria, where the Chameleon Dragon has never been recorded (but which has been little surveyed).

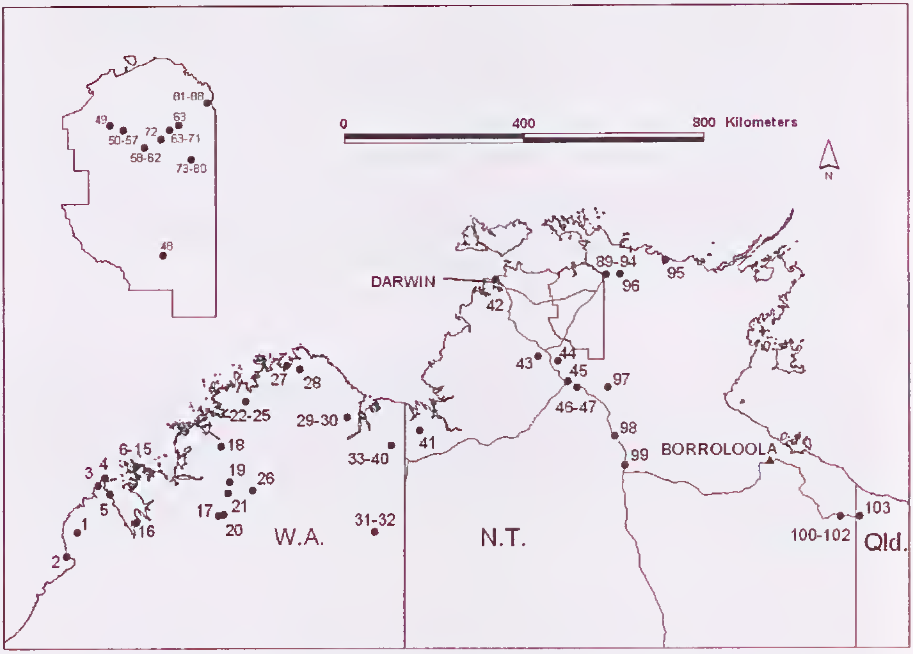

Figure 1. Distribution of the Chameleon Dragon. Location numbers are listed in the Appendix. The scale bar relates to the main map. The inset map is Kakadu National Park in the Northern Territory.

Western Australia

In WA the majority of records are specimen-based, with records from the Dampier Peninsula, Derby and Leopold Ranges area. Storr *et al.* (1983) list far north Western Australia including the Kimberley to Coulomb Point, King Leopold Range and Kununurra in its range. There are several records throughout the north Kimberley, Drysdale River National Park and Kalumburu area, but few from the central Kimberley Plateau, probably reflecting the lack of survey effort and inaccessibility of this area. Residents of Kununurra reported several observations of Chameleon Dragon within the town over the past 25 years (particularly at caravan parks), and there are two records from Bungle Bungle National Park (including a specimen).

Northern Territory

In the NT there is one record of this dragon from the far west, from Spirit Hills Station near Kununurra, with a major gap in distribution records between the Victoria-Bonaparte and Daly Basin districts (probably reflecting low survey effort in

this remote area). Similarly there is only one historical record of Chameleon Dragon for the Darwin area. Many biologists are based in Darwin, so this may represent a real range gap. Almost half of all known records are from Kakadu National Park (KNP) (particularly Kapalga Research Station, Jabiru, Nourlangie and Ubirr Rock) and Oenpelli in western Arnhem Land, highlighting the high field survey effort. There are several records for the Katherine and Mataranka districts, with only two in the Daly Waters-Sturt Plateau area (including Husband 1979). There are two (or three) records from the far west of the NT Gulf Region on Wollogorang Station. The pattern of records for the NT appears to reflect previous survey effort, but the increased frequency of records from the higher rainfall forests may also relate to a habitat preference.

Queensland

The Chameleon Dragon was included on the official wildlife list for Qld in 1991 (Covacevich and Couper 1991) because of 'an unambiguous photo' of a Chameleon Dragon taken in 1978 at 'Camp Ridgeway', between the NT/Qld border and the Westmoreland Station homestead by a geologist (H. Cogger, pers. comm.). It was subsequently removed from the list because no specimens were available (P. Couper, pers. comm.).

Habitat use

The Chameleon Dragon prefers eucalypt forests and woodlands, with few records from dry tropical forest (monsoon rainforest), floodplain, acacia woodland and urban areas (Cogger 1981; this review). There were two records from tropical dry forest (Figure 2) including a Wollogorang record where an individual was collected from a small patch of forest. Apart from the record by Husband (1979) from acacia woodland (presumably Lancewood *Acacia shirleyi* scrub), there was a single specimen collected from the same habitat near Kalumburu by the Australian Museum. One naturalist observed a Chameleon Dragon sleeping in 'Pindan' acacia trees north of Broome and suspects that they might be associated with acacia shrubland on deep sand (I. Morris, pers. comm.) but none were recorded during biological surveys targeting such shrubland (Woinarski & Fisher 1995a,b). There are two reports from the vicinity of towns: at Kununurra and Oenpelli, and several more undocumented reports from Jabiru (G. Miles, pers.comm.) (see Appendix).

Behaviour and microhabitat use

Chameleon Dragons are mostly arboreal and sedentary. Individuals are repeatedly observed at regular points along roads in KNP indicating that they occupy permanent territories (I. Morris, pers. comm.). A total of 10 individuals have been captured in pitfall traps in KNP (T. Hertog, pers. comm) and at Kalumburu (J. Wombey, pers. comm.). Trap capture rates are exceptionally low as the KNP data represent c. 4,000 pitfall trap nights over a 7 year period. Chameleon Dragons are most often observed

on the ground (on tracks, as road-killed individuals, basking, fighting or digging burrows), six have been observed low in trees and none have been recorded from the canopy (Table 1) although it is suspected that they spend most time at this level. They are probably experts at evasion, as they 'slip around the tree to avoid predators' (N. Gambold, pers. comm.). They are also inexplicably clumsy. One individual landed on the windscreen of a moving car, apparently after being captured and then released by a diurnal raptor (Museum and Art Gallery of the Northern Territory database). A Chameleon Dragon fell from the canopy of *Eucalyptus* woodland in Kakadu (A. Dudley, pers. comm.), and at Wollogorang a dragon fell from the canopy of eucalypt woodland onto a tent (C. Trainor, pers. obs.). Tony Griffiths (pers. comm.) observed a released animal climb, then fall off the lower trunk of a tree.

Little is known of diet. In Kakadu an adult male road-killed on 5 July 2002 had: "Stomach quite full; contained about 80 green ants [Green Ants *Oecophylla smaragdina*], plus 4-5 square bits of bark. There was a fecal pellet in intestine, also wholly green ants" (S. Sweet, pers. comm.). A juvenile dragon has been observed feeding on Green Ants (I. Morris, pers. comm.). A ranger observed a juvenile sleeping/basking on a tree root in KNP (L. Barnett *per* I. Morris, pers. comm.). After release, a male animal at Kapalga slowly moved 2 m then climbed a *Eucalyptus tetrodonta* tree, moving its limbs slowly with little use of its hind feet while climbing. The tail is prehensile, and during this observation it was used to grip branches and other objects (T. Griffiths, pers. comm.).

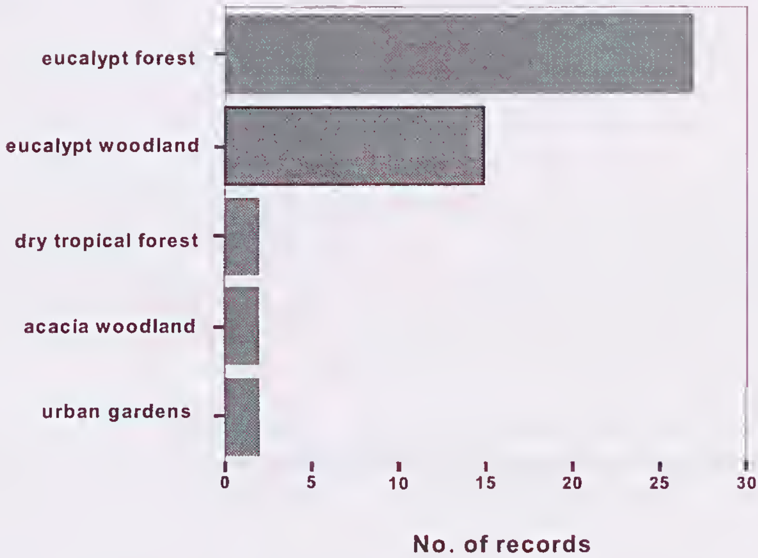

Figure 2. Frequency of occurrence of the Chameleon Dragon in broad habitat types.

Table 1. Frequency of occurrence of microhabitat use (including pitfall trap) by Chameleon Dragon when first sighted (*n* = 41 records). * = includes two records of an animal that fell to ground from the forest canopy, and one that was dropped to ground by a diurnal raptor.

Microhabitat	Frequency
Pitfall trap capture	10
On low tree (<2 m)	6
On ground: stationary or crossing track	10
On ground	5 *
On ground: road kill	4
On ground: digging burrow	2
On ground: territorial fight	2
On ground: with predator	1
On ground: basking	1

Breeding, seasonality and detectability

Half of the 75 dated locality records are from July, August and September (Figure 3). Males are usually observed in May (5 of 9 records where sex known), and females in July and August (9 of 12 records where sex known). Presumably males descend at this time to take part in territorial fighting to establish mating rights (see below). In the following months, gravid females descend to the ground to lay eggs, with several direct observations of this behaviour (J. Wombey, pers. comm.). A juvenile dragon (snout-vent 53 mm, weight 3 g) was captured on 19 January 1979 (N. Sonnemann, pers. comm.), probably having hatched in the late dry season (September-October).

Basking by gravid females may increase detectability because they are heavier and less mobile than non-gravid individuals (G. Miles, pers. comm.). An adult female, suspected of being gravid, 'walked in a slow, rather jerky gait' after being released (J. Wombey, pers. comm.). Females are known to lay eight eggs (G. Miles, pers. comm.). The egg number, incubation period, egg and hatchling morphometrics of a purported single clutch was described by Pengilley (1982), but he had described the characteristics of two clutches rather than one (G. Miles, pers. comm.). It has been speculated that in the wet season they 'prefer sandy substrates which are boggy and impassable in the wet season', which may further reduce opportunities to observe dragons in this season (G. Miles, pers. comm.). The Chameleon Dragon may have

been observed less frequently in KNP since roads were upgraded to bitumen (c. 1985), because the black surfaces are too hot for basking and visual detection is reduced (I. Morris, pers. comm.).

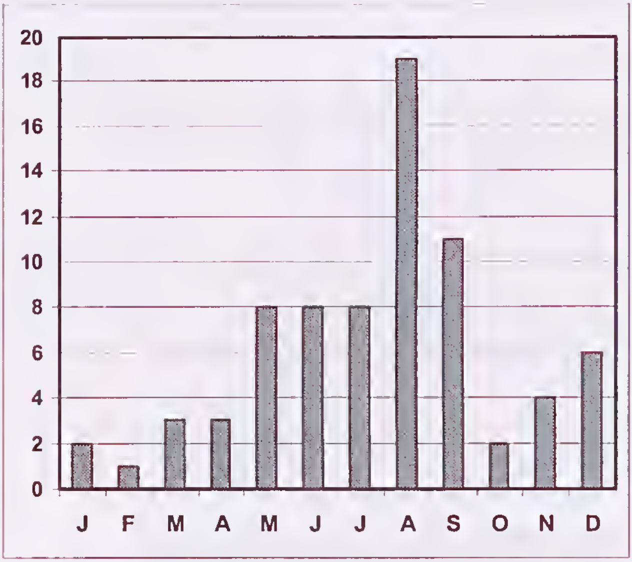

Figure 3. Number of monthly records of the Chameleon Dragon (n = 75 dated records).

Relative abundance

Little is known of the Chameleon Dragon's relative abundance, but field observations are infrequent. Several experts consider that they are not rare, but difficult to record unless gravid (P. Harlow and J. Wombey, pers. comm.) or involved in territorial fights. The number of records has increased greatly over the last three decades of the 20th century, with the intensification of biological field survey in northern Australia.

Major fauna surveys have been notably unsuccessful at recording Chameleon Dragons: one was recorded during surveys of KNP Stages 1 and 2 over about 3 person years (Braithwaite 1985); none were recorded in the KNP Stage 3 survey, involving about 200 person days (Woinarski & Braithwaite 1991), or during a Bungle Bungle National Park survey (Woinarski 1992). None were recorded during surveys of Litchfield, Elsey or Limmen Gate Nat. Parks (Griffiths 1997, Griffiths *et al.* 1997ab) or the continental Wessel and English Company Islands (Woinarski *et al.* 1999).

There are two confirmed observations of more than one individual. On 1 May 1979, two males were observed in a territorial fight in KNP, and then a female was observed nearby on the same day (J. Wombey, pers. comm.). At Kapalga, during June 1992, two males were observed by the author on the ground clasping each other's bodies while presumably fighting. Additionally, a total of 10 individuals were collected from the Wotjulum area of WA in 1954-1955 during museum surveys, which comprise almost all the records for that decade. Four individuals were observed in one day by a 'Mr Bishop' (N. Gambold, pers. comm.). At Kununurra four Chameleon Dragons were observed over 10 months in 1978-1979 (N. Sonnemann, pers. comm.) and in the Jabiru area of KNP, about eight Chameleon Dragons were collected over a 22 yr period (G. Miles, pers. comm.).

Possible threats

Hot late season fires which burn into the canopy would be the greatest threat to Chameleon Dragon populations, as most individuals would be killed by this regime. Limited data from the Kapalga Fire Experiment provides some support for this opinion. During reptile sampling, only seven Chameleon Dragons were captured over five years. Four were recorded in control years before the burning began (two in progressive burn samples and two in late burn samples). After the experiment began, Chameleon Dragons were recorded only in unburnt or early burn sites (T. Hertog, pers. comm.; the author, pers. obs.). Predation by Feral Cats *Felis catus*, has been suggested as threats to dragons (N. Gambold, pers. comm.; B. Hancock, pers. comm.). A cat was observed mauling a Chameleon Dragon at Kununurra (N. Sonnemann, pers. comm.). Chemical spraying (with dieldrin) has also been suggested as a cause of the reduced frequency of observations of dragons in the vicinity of the town of Jabiru (I. Morris, pers. comm.).

Conservation and suggestions for further study

Although rarely recorded, the Chameleon Dragon is not considered globally threatened (http//www.redlist.org, 2005) or regionally rare or threatened, however Gambold and Menkhorst (1992) used the presence of Chameleon Dragons as supporting evidence for a National Estate proposal. More than half of the 103 records are from protected areas (Table 2), reflecting survey effort in designated protected areas and presumably demonstrating that the network provides good coverage of dragon habitat.

There are at least 58 museum specimens (see Appendix) that could be analysed for study of diet, reproduction and genetics. Field studies will need to focus on active searching during the early and mid-dry season when males and females descend to the ground to mate and lay eggs. Pitfall trapping has rarely been successful. The Kununurra area, particularly around caravan parks, KNP area, Kalumburu and Cape Leveque may be suitable locations for field study. The Bardi people (at least) of the Dampier Peninsula are reputedly familiar with the Chameleon Dragon (I. Morris, pers.

comm.). Questionnaires and interview with Aboriginals over the range of the species, aiming to document local knowledge of occurrence, habitat use and behaviour also has potential to reveal new ecological details of this elusive dragon lizard.

Table 2. Frequency of Chameleon Dragon records ($n = 60$) from protected areas and Aboriginal Land Trusts in north-western Australia.

Protected areas	*Area (km^2)*	*No. records*
Kakadu National Park (KNP)	20,000	42
Umbrawarra Gorge Nature Park	20	1
Point Coulomb Nature Reserve	c. 200	1
Drysdale River National Park	7,000	3
Bungle Bungle National Park	3,100	2
Cutta Cutta Caves Nature Park	20	2
Arnhem Land Aboriginal Land Trust	c. 60,000	8
Prince Regent River Nature Reserve	6,300	1

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Museum, London), Keith McDonald (QLD), Greg Miles (Department of Environment and Heritage, Jabiru), Nic Gambold (Central Land Council, Alice Springs), Ian Morris (Noonamah, NT), Cassy Redhed (Chicago Field Museum), Ross Sadlier (Australian Museum, Canberra), M. Ruf (Zoological Museum of Zurich), Rick Shine (University of Sydney), Martin Shultz (Southern Cross University), Neil Sonnemann, Laurie Smith (Westerm Australian Musem, Perth), Sam Sweet (University of California), Steve Wilson (Queensland Museum, Brisbane) and John Wombey (Australian National Wildlife Collection, CSIRO, Canberra).

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Appendix. Chameleon Dragon locality record details.

This appendix may be viewed at:
http://www.geocities.com/ntfieldnaturalists/journal/Trainor_appendix.pdf

The Chameleon Dragon *Chelosania brunnea* is arboreal, although females descend to the ground to dig nest holes. (Martin Armstrong)

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Avian granivores consume flowers, not just seed, of the Top End Bamboo *Bambusa arnhemica*

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"Who eats bamboo seed? Everybody does." So wrote Janzen (1976) in his classic work on the gregarious flowering and subsequent die-off of many bamboos. Janzen collated a large anecdotal record demonstrating aggregation (often in huge numbers) at flowering stands of bamboo, and consumption of bamboo seed, by humans, many species of rodent, pigs, elephants, rhinoceros, a range of bovids and cervids, monkeys, a variety of birds, and insects. During a drought in India, an estimated 35 000 people survived on bamboo seed (Lowrie 1900 cited in Janzen 1976). Mass-flowering events are often followed by rodent plagues (Chauhan & Saxena 1985, Jaksic & Lima 2003). At least one bird species, the Pied Mannikin *Lonchura fringilloides* of East Africa, appears to be a bamboo seed specialist (Jackson 1972).

The seeds of most bamboos are large, nutritious grains (caryopses) that lack defensive toxins (Pathak 1979, Bhargava *et al.* 1996). Janzen (1976) proposed that the peculiarly infrequent gregarious-flowering behaviour and subsequent death of certain bamboos was an evolutionary response to the vulnerability of its seeds to consumers, in which huge production of seed alternates with many years of no production at all, the latter ensuring that populations of seed consumers cannot build up to match the abundance of the resource - the *seed predator satiation hypothesis*. Effective seed predator satiation during a mast-fruiting event, and subsequent total failure of seed under unsatiated conditions, has been documented in Bornean dipterocarps (Curran & Webb 2000). However, the improved pollination rates achievable by wind-pollinated species when neighbours are flowering, along with several other possibilities, are potential additional or alternative explanations for the adaptive value of infrequent but massive fruiting events (Kelly 1994, Sakai 2002).

Bambusa arnhemica, a bamboo endemic to the north-western Top End of the Northern Territory, flowers gregariously at intervals of *c.* 40–50 years and seeds prolifically (Franklin 2004). Simple or compound flowering branches up to 2.5 m long bear clusters (inflorescences) of pseudospikelets at each node. In this note, I report observations, obtained in the course of studies of *B. arnhemica* flowering behaviour, of birds consuming plant material from the inflorescences of *B. arnhemica*. When I located birds amongst standing *B. arnhemica* inflorescences, I examined them through binoculars. If any individual was observed consuming any part of the inflorescence (*cf* probing in apparent search of insects), I noted the species, and counted or estimated the flock size. To maximise independence of records, a bird species was

recorded in this way at a maximum of one location per day. I also report aviary trials to test my suspicions about what the birds were consuming.

I obtained 93 observations of 11 bird species foraging on the inflorescences of *B. arnhemica*, comprising four cockatoo, three parrot and four finch species (Table 1). Reflecting where I spent most time in flowering bamboo stands, 83 records (89%) were in the Adelaide River catchment, the remainder being shared between the Daly, Finniss and Mary River catchments. Reflecting the main flowering and seeding times of *B. arnhemica* (Franklin, unpubl.), 89 (96%) of records were within the period July to December, with a peak in October (28 records, 30%). The most frequently recorded and numerous species were Rainbow Lorikeet and Chestnut-breasted Mannikin, followed by Double-barred Finch and Red-tailed Black-Cockatoo. Rainbow Lorikeets fed particularly persistently, moving slowly from inflorescence to inflorescence in a manner that could feasibly have serious adverse affects on the productivity of clumps, especially if only isolated clumps were flowering. Mannikins, on the other hand, tended to move through an area, feeding fairly briefly on each clump. Cockatoos may be relatively under-reported because they were often wary and flushed before I could confirm their behaviour. Several small honeyeater species, notably the White-throated Honeyeater *Melithreptus albogularis* and the Brown Honeyeater *Lichmera indistincta*, were frequently recorded probing inflorescences, but I saw no evidence that they were consuming plant material. Granivorous birds were also observed foraging on the ground below flowering or recently-seeded bamboo clumps, but the identity of the food being consumed could not be confirmed.

Table 1. Birds observed feeding at inflorescences of wild bamboo *Bambusa arnhemica*.

Species	No. of records	Median flock size (range)
Cacatuidae		
Red-tailed Black-Cockatoo *Calyptorhynchus banksii*	9	10 (2-100)
Galah *Cacatua roseicapilla*	1	4 (4)
Little Corella *Cacatua sanguinea*	4	8.5 (7-13)
Sulphur-crested Cockatoo *Cacatua galerita*	4	1 (1-2)
Psittacidae		
Rainbow Lorikeet *Trichoglossus haematodus*	21	5 (2-60)
Red-winged Parrot *Aprosmictus erythropterus*	7	2 (1-4)
Northern Rosella *Platycercus venustus*	5	2 (1-5)
Passeridae		
Double-barred Finch *Taeniopygia bichenovii*	14	3 (1-10)
Long-tailed Finch *Poephila acuticauda*	1	8 (8)
Crimson Finch *Neochmia phaeton*	7	2 (1-5)
Chestnut-breasted Mannikin *Lonchura castaneothorax*	20	10 (1-30)

I started with the assumption that the listed bird species were seeking and consuming bamboo seed, but soon became suspicious that this was frequently not the case. I noticed that bird activity at the inflorescences appeared related to flowering *per se* and not to my unquantified observations about seed availability, the latter being sparse except in October or November. On a number of occasions when I saw much active foraging amongst the inflorescences, I made an effort to locate seed on them, but found few. Furthermore, the rapid and repetitive bill movements of foraging granivores that I observed repeatedly was hardly consistent with either direct consumption or fragmentation of seeds. So far as I could determine, finches and Rainbow Lorikeets appeared to be chewing 'empty' green florets, but I could not determine what the cockatoos were consuming.

My suspicions that flowers were being consumed were further raised when I measured *B. arnhemica* seeds. These are grains with a mean air-dry weight of 19.3 mg and mean dimensions of 7.6 by 2.1 mm (Franklin 2003). They weigh 3.2 times as much as seeds of Annual Spear-grass *Sarga intrans* and 1.5 times those of Giant Spear-grass *Heteropogon triticeus* (Dostine & Franklin 2002). In a study of finch diets (Gouldian *Erythrura gouldiae*; Masked *Poephila personata*; and Long-tailed *P. acuticauda*; Dostine & Franklin 2002), seeds of *S. intrans* were the largest seed consumed whole, those of *H. triticeus* being consumed only after being fragmented. As Crimson Finch and especially Double-barred Finches are smaller-bodied and have smaller bills than any of these species (Franklin, unpubl.), and bill size in Australian grass-finches is directly related to the size of seed consumed (Todd *et al.* 2003), it seemed most unlikely that these birds could swallow whole *B. arnhemica* seeds.

To test the interest of birds in inflorescences lacking seed, and to identify what else they might be consuming, I collected sections of *B. arnhemica* flowering branches, each around 15-20 cm long and containing two or three inflorescences, from the Adelaide River. I checked each section thoroughly and removed the few ripe or un-ripe seeds, which were readily detected by the swollen firmness of the floret. On the same afternoon, I took them to the Territory Wildlife Park, where two to three sections were placed in each of four small aviaries, either attached to the wire or on the ground (as advised by keeping staff based on what the birds were used to). Aviaries were selected to represent a range of the finches and parrots available including, where possible, the species listed in Table 1. The birds' response was observed from a distance of from 3–5 metres for about 10 minutes.

Rainbow Lorikeets and Hooded Parrots showed no sign of interest in the branch sections, and after several 'exploratory' pecks they were ignored by Pictorella Mannikins (Table 2). However, Yellow-rumped Mannikins, Gouldian Finches and one Red-winged Parrot fed persistently and systematically on the inflorescences. The Red-winged Parrot worked over each inflorescence, breaking off most or all of an entire pseudospikelet before running it sideways through its bill and masticating it thoroughly, then dropping the remaining green material (the lemma and palea).

Yellow-rumped Mannikins worked along the spikelets, often removing one or more florets and masticating them, shedding the green matter afterwards. Gouldian Finches pecked persistently at the inflorescences, working along the spikelets, but did not obviously remove anything. In the case of Yellow-rumped Mannikins and the Red-winged Parrot, it was clear that the internal contents of the florets, and not the outer glumes, were sought and consumed, and that these were obtained by squeezing out the contents. It is not clear what the Gouldian Finches were doing or obtaining, but they could have been obtaining droplets or fragments left by the mannikins. The observed foraging behaviour by Yellow-rumped Mannikins and the Red-winged Parrot was consistent with what I had observed in the wild.

Table 2. Response of aviary birds to provision of seedless *Bambusa arnhemica* inflorescences, 22 August 2001.

Aviary	Species	Response to inflorescences
1	2 Red-winged Parrots *Aprosmictus erythropterus* 2 Rainbow Lorikeets *Trichoglossus haematodus*	one Red-winged Parrot systematically consumed them
2	*c.* 15 Pictorella Mannikins *Heteromunia pectoralis*	initial interest only; no consumption
3	*c.* 15 Gouldian Finches *Erythrura gouldiae* 5 Yellow-rumped Mannikins *Lonchura flaviprymna*	persistent consumption by both species, repeated when a second batch of inflorescences were provided
4	4 Hooded Parrots *Psephotus dissimilis*	no sign of interest

The contents of *B. arnhemica* florets, comprising the ovary, lodicules, stigmas and stamens, are evidently of considerable interest as a food source to a range of birds. Whilst such foraging behaviour is not surprising in the dietarily versatile Rainbow Lorikeet and other parrots, and perhaps also amongst cockatoos (Higgins 1999), there is no precedent for it amongst Australian finches which are regarded as either strictly granivorous or seasonally somewhat insectivorous (Immelmann 1982, Read 1994, Dostine & Franklin 2002, Todd *et al.* 2003). Todd *et al.* (2003) did, however, report that Crimson Finches consumed lerp, a soft carbohydrate exudate produced by psyllids. There appear to be no published studies of the diet of the main finch species involved here, the Chestnut-breasted Mannikin and Double-barred Finch, but it may be of relevance that these two species and especially the mannikin are somewhat noteworthy for the frequency with which they forage from standing grass stems rather than on the ground (Immelmann 1982), a habit which might predispose them to arboreal foraging on bamboo.

Janzen (1976) cited records of Burmese jungle fowl and African monkeys feeding on bamboo flowers. Insects may damage bamboo florets (John *et al.* 1995, Koshy & Harikumar 2001). This suggests yet another dimension to the vulnerability of long-lived bamboos during the brief phase of sexual reproduction that precedes death. The value of highly synchronised flowering in satiating consumers, as postulated by the *seed predator satiation hypothesis*, may also apply to 'predators of flowers'.

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Seed-eating birds avidly consume flowers of the Top End Bamboo *Bambusa arnhemica*. (Don Franklin)

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A population count and ecological notes for the little-known terrestrial orchid *Didymoplexis pallens*

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Didymoplexis pallens Griff. is a leafless, saprophytic, terrestrial orchid. Its small white flowers open one at a time in a raceme atop an unbranched, 10–15 cm, pink, fleshy stem. For most of the year it persists underground as a tuber, emerging to flower and fruit following early wet season rains (Jones 1988). The species is known from Queensland, Northern Territory, Western Australia, Indonesia, Malaysia and India, but is considered "elusive" (Hooker 1894, Jones 1988). In the Northern Territory (NT), Liddle *et al.* (1994) mapped its occurrence at two locations in the Daly River catchment and two in central Arnhem Land. It has since been located on Melville Island (NT Herbarium record). On the basis of the sparsity of records and limited and anecdotal information about its occurrence, the species has been classified for the NT as Data Deficient (DIPE 2002).

In this note, we provide details of a sixth NT location for *D. pallens* including a population count and brief ecological notes. The population was discovered by one of us (Franklin 2003) during the course of a study of the Top End Bamboo *Bambusa arnhemica* at Mary River Park (12°54'30" S, 131°39'30" E), a private ecotourism facility, in November 2001. At the time, an estimated 100 individuals were found growing under bamboo clumps on the bank of a billabong embedded in the floodplain of the Mary River approximately one kilometre upstream from the Arnhem Highway bridge over the Mary River.

On 2 December 2003, we conducted a search for the species over about 3 km of billabong bank at Mary River Park, including the area of the original discovery. We located *D. pallens* intermittently over a 1.2 km length of bank, and counted exactly 700 individuals, of which an estimated 90% were in flower and 10% in fruit.

Most *D. pallens* were found growing in bamboo leaf litter. Some were under other riparian trees, shrubs or vines – *Phyllanthus reticulatus*, *Ficus scobina*, *Lophostemon lactifluus* and *Gymnanthera oblonga*, and a few under a light cover of the grass *Paspalidium distans* that occurs in open areas immediately above the riparian forest. The soils supporting *D. pallens* were alluvial, grey clay-loams and, perhaps surprisingly for soils supporting a saprophyte, not notably humic. All sites are prone to inundation (Franklin, pers.

obs.), most often during the mid- to late-wet season after flowering and fruiting have finished. We did not locate any *D. pallens* in the lower slope of the riparian forest where inundation may be prolonged and occurs earlier in the season. *Didymoplexis pallens* tubers and presumably also seed are thus tolerant of waterlogging, but excess and/or early waterlogging may limit its occurrence, a strikingly similar ecological pattern to that of the bamboo under which it occurs at Mary River (Franklin & Bowman 2004).

Didymoplexis pallens is not exclusively associated with bamboo. Notes accompanying previous herbarium collections for the NT indicate occurrence in a variety of damp and/or poorly-drained situations, including a seepage area on the margin of monsoon rainforest in sandstone country, amongst sedges at the edge of a spring-fed monsoon rainforest, in leaf litter in vine forest along a river, and on a swampy plain treeless but for some *Pandanus*.

Reasons for the patchiness and scarcity of *D. pallens* in the NT, its response to fire, and the threats facing it, if any, are speculative. The Mary River site was subject to an intense wildfire in August 2001, and *D. pallens* was observed on burnt ground in the following November (Franklin 2003). The area was not burnt for at least several years prior to 2001, and has not been burnt since. Tuberous plants are particularly susceptible to disturbance by Feral Pigs *Sus scrofa* (e.g. Fensham 1993) and possibly also Asian Water Buffalo *Bubalus bubalis*. Herbarium notes associated with one of the Arnhem Land sites report heavy disturbance by buffalo. Under current management, there are no buffalo in the riparian forest areas of Mary River Park. An active control program for feral pigs has been successful in reducing them to low levels in the area where we found *D. pallens*, as evidenced by notably low levels of impact on bamboo shoots compared to other sites (Franklin, unpubl.).

Based on the available evidence of limited extent of occurrence and apparently small population, a case could be made for classifying *D. pallens* as Vulnerable in the NT. However, plants are evident above ground for just a few weeks each year (Franklin 2003) and at a time when the weather is particularly unfavourable for field surveys, so it may readily be overlooked in other areas. Annual fluctuations in the number of orchids that emerge seasonally from tubers (Gillman & Dodd 1998) may overstate real population fluctuations because of tuber dormancy (Brzosko 2003, Kery & Gregg 2004). We therefore recommend that *D. pallens* continue to be classified as Data Deficient in the NT, and that further survey and study of the population dynamics of, and threats to the species, be undertaken.

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Birds of Lake Nongra and surrounding bushland, Northern Territory

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Lake Nongra is a large freshwater lake situated in the southern-most part of the pastoral country on the northern margin of the Tanami Desert in the Northern Territory. The lake is located at the northern edge of range for many arid zone birds and at the southern edge of range for many sub-tropical zone birds. The area is rarely visited and it appears that the last comprehensive bird survey of the lake was undertaken in 1993, when 29 waterbird species were recorded (Jaensch 1994). The birds reported here were recorded during eight surveys conducted over a 23-day period during October-November 2002. In addition, a brief survey was undertaken in June 2002 when water levels were about 1 m higher than in October-November. I observed 17 waterbirds not previously recorded, did not record 5 seen previously and also recorded 54 bushbirds around the lake foreshore.

The lake, when full, is shallow with a maximum depth of 1.5–2 m. It was last dry about 10 years ago and is currently only 0.3 m deep and very restricted in areal extent (T. Westerway, Inverway Station, pers. comm., Sept. 2005). It is filled by summer rains. During the October-November surveys the lake was less than at full capacity (Figure 1), being at its widest points 9 km north-south and 5–6 km east-west and was dominated by open water. In places patches of thick, dead bushes, 2–4 m high, extended 100–200 m into the lake. These occur particularly in the north-west but also along parts of the north-eastern and eastern shoreline and along creek inlets into the lake. The lake margin, 50–500 m wide, is flat and during the survey period was covered by short, ephemeral grasses and herbs except for 2–30 m wide mudflats exposed along the edge of the lake and along some creek channels. The surrounding bush is dominated by open eucalypt and acacia woodland with an understory of grass although along creek lines the vegetation is more complex and relatively dense.

The lake straddles the boundary of Inverway and Birrindudu pastoral leases. On Inverway the lake is fenced off from cattle, however on Birrindudu the paddock containing the lake is used as a drought refuge and is usually not grazed except by stray cattle. Few recent cattle tracks were seen along the shoreline. However, due to dry conditions there were plans to re-introduce cattle into this paddock. Several camels were seen drinking from the lake during the October-November surveys.

The eight surveys were each of 1.5–2.5 hour duration and covered an area of about 500 m radius with the centre point taken on the edge of the lake except for the southern-most site which was along a creek line (Figure 1). Large parts of the lake

were not surveyed. In addition, the thickets of dead bushes present in places around the lake prevented the observation of probably many hundreds of waterbirds sheltering from windy conditions that prevailed during many of the surveys. Leica x10 binoculars were used for observations, so for the smaller waterbirds only those relatively close to the shore could be identified. In June most of the many hundreds of waterbirds seen at the single site visited were well off-shore and were not identified. Because of its incomplete nature only one species from this survey (Blue-billed Duck), not seen in the later surveys, is included in Table 1. During the October-November surveys most waterbirds were sheltering close to the shore from the windy conditions and a high proportion of birds observed within each survey area were identified.

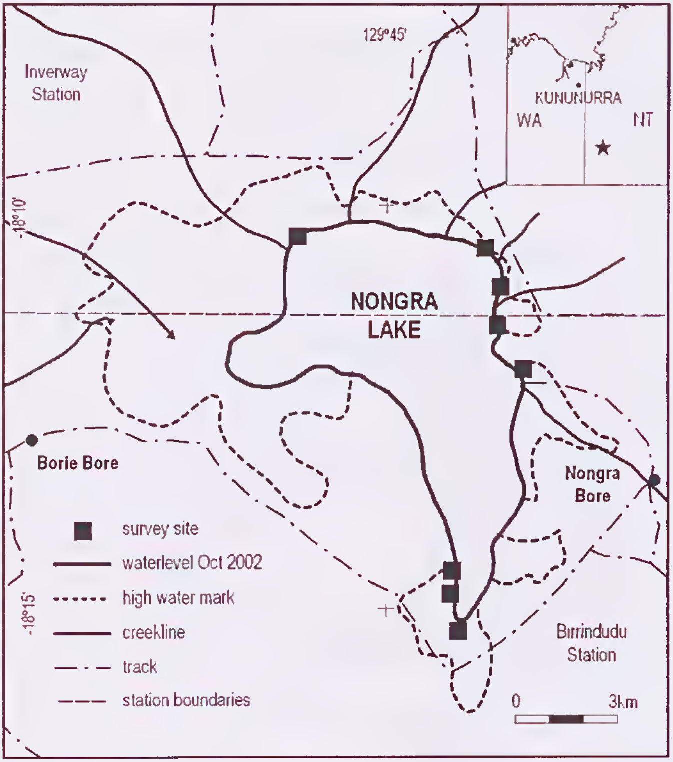

Figure 1. Location of survey sites around the margin of Lake Nongra undertaken in October-November 2002. The heavy outline of the lake is its approximate position in October 2002 whereas the dotted line is the lake outline as shown on the 1:100 000 scale topographic map.

Table 1. Birds seen at Lake Nongra between 14/10/02 and 5/11/02.

Bird Species	Number of surveys (n = 8)
Magpie Goose *Anseranas semipalmata*	1
Blue-billed Duck *Oxyura australis*	1
Freckled Duck *Stictonetta naevosa*	3
Black Swan *Cygnus atratus*	3
Australian Wood Duck *Chenonetta jubata*	1
Pacific Black Duck *Anas superciliosa*	7
Grey Teal *Anas gracilis*	8
Pink-eared Duck *Malacorhynchus membranaceus*	7
Hardhead *Aythya australis*	8
Australasian Grebe *Tachybaptus novaehollandiae*	1
Great Crested Grebe *Podiceps cristatus*	3
Darter *Anhinga melanogaster*	7
Little Pied Cormorant *Phalacrocorax melanoleucos*	3
Little Black Cormorant *Phalacrocorax sulcirostris*	6
Australian Pelican *Pelecanus conspicillatus*	8
White-faced Heron *Egretta novaehollandiae*	3
Little Egret *Egretta garzetta*	4
White-necked Heron *Ardea pacifica*	2
Great Egret *Ardea alba*	7
Glossy Ibis *Plegadis falcinellus*	8
Straw-necked Ibis *Threskiomis spinicollis*	3
Royal Spoonbill *Platalea regia*	5
Yellow-billed Spoonbill *Platalea flavipes*	5
Black-shouldered Kite *Elanus axillaris*	1
Whistling Kite *Haliastur sphenurus*	5
Spotted Harrier *Circus assimilis*	1
Swamp Harrier *Circus approximans*	1
Brown Goshawk *Accipiter fasciatus*	1
Collared Sparrowhawk *Accipiter cirrhocephalus*	1
Wedge-tailed Eagle *Aquila audax*	2
Brown Falcon *Falco berigora*	2
Australian Hobby *Falco longipennis*	2
Nankeen Kestrel *Falco cenchroides*	2
Brolga *Grus rubicunda*	4
Purple Swamphen *Porphyrio porphyrio*	1
Black-tailed Native-hen *Gallinula ventralis*	4
Eurasian Coot *Fulica atra*	4
Australian Bustard *Ardeotis australis*	2
Marsh Sandpiper *Tringa stagnatilis*	3
Common Greenshank *Tringa nebularia*	5
Wood Sandpiper *Tringa glareola*	1
Common Sandpiper *Actitis hypoleucos*	2
Black-winged Stilt *Himantopus himantopus*	8
Red-capped Plover *Charadrius ruficapillus*	2
Oriental Plover *Charadrius veredus*	1
Black-fronted Dotterel *Elseyornis melanops*	4
Red-kneed Dotterel *Erythrogonys cinctus*	7

Bird Species	Number of surveys (n = 8)
Masked Lapwing *Vanellus miles*	5
Gull-billed Tern *Sterna nilotica*	7
Caspian Tern *Sterna caspia*	2
Whiskered Tern *Chlidonias hybridus*	7
Crested Pigeon *Ocyphaps lophotes*	4
Peaceful Dove *Geopelia striata*	2
Red-tailed Black-Cockatoo *Calyptorhynchus banksii*	4
Galah *Cacatua roseicapilla*	1
Little Corella *Cacatua sanguinea*	3
Australian Ringneck *Barnardius zonarius*	2
Budgerigar *Melopsittacus undulatus*	1
Pallid Cuckoo *Cuculus pallidus*	1
Pheasant Coucal *Centropus phasianinus*	1
Tawny Frogmouth *Podargus strigoides*	1
Sacred Kingfisher *Todiramphus sanctus*	2
Rainbow Bee-eater *Merops ornatus*	2
Red-backed Fairy-wren *Malurus melanocephalus*	4
Striated Pardalote *Pardalotus striatus*	1
Weebill *Smicrornis brevirostris*	4
Spiny-cheeked Honeyeater *Acanthagenys rufogularis*	1
Little Friarbird *Philemon citreogularis*	4
Yellow-throated Miner *Manorina flavigula*	5
Singing Honeyeater *Lichenostomus virescens*	4
Grey-fronted Honeyeater *Lichenostomus plumulus*	4
Yellow-tinted Honeyeater *Lichenostomus flavescens*	2
Brown Honeyeater *Lichmera indistincta*	4
Rufous-throated Honeyeater *Conopophila rufogularis*	4
Jacky Winter *Microeca fascinans*	4
Grey-crowned Babbler *Pomatostomus temporalis*	2
Rufous Whistler *Pachycephala rufiventris*	5
Grey Shrike-thrush *Colluricincla harmonica*	1
Restless Flycatcher *Mylagra inquieta*	5
Magpie-lark *Grallina cyanoleuca*	8
Willie Wagtail *Rhipidura leucophrys*	7
Black-faced Cuckoo-shrike *Coracina novaehollandiae*	6
White-winged Triller *Lalage sueurii*	7
White-breasted Woodswallow *Artamus leucorynchus*	8
Black-faced Woodswallow *Artamus cinereus*	8
Little Woodswallow *Artamus minor*	1
Pied Butcherbird *Cracticus nigrogularis*	7
Australian Magpie *Gymnorhina tibicen*	1
Torresian Crow *Corvus orru*	3
Singing Bushlark *Mirafra javanica*	1
Richard's Pipit *Anthus novaeseelandiae*	4
Zebra Finch *Taeniopygia guttata*	3
Tree Martin *Hirundo nigricans*	1
Fairy Martin *Hirundo ariel*	7
Rufous Songlark *Cincloramphus mathewsi*	1

All 41 waterbirds and 54 bushbird species observed are listed in Table 1. Taxonomic order and nomenclature follow Christidis and Boles (1994).

Waterbirds

The most common species seen were Grey Teal and Hardhead with estimated numbers of >100 to >1000 in most surveyed areas. Pacific Black Duck was also common with numbers of 50 to >500 per site. Black Swan, Pink-eared Duck, Darter, Australian Pelican, Royal Spoonbill and Yellow-billed Spoonbill all occurred in similar numbers of 10-20 at most sites. Moderate numbers (75 to >150) of Eurasian Coot occurred in four of the northern sites. Freckled Duck were seen only in the three most northerly sites in low numbers (10–20). Freckled Duck are regularly reported from Lake Gregory, 330 km southwest of Lake Nongra and situated in a similar arid to sub-tropical transition zone (Halse *et al.* 1998). They also occur at Lake Woods, 400 km to the east. They are, however, rarely reported from elsewhere in the northern part of Australia (Marchant & Higgins 1990, Barrett *et al.* 2003).

Red-kneed Dotterel was the most common wader and along with Black-winged Stilt occurred in numbers of 10 to >30 in all except one site. Other waterbirds present at most survey sites were Glossy Ibis (2–3 birds per site), Great Egret (0–5), Little Black Cormorant (0–10), Whiskered Tern (0–15), Gull-billed Tern (0–3), Common Greenshank (0–5), and Black-tailed Native-hen (10–30). All other waterbirds were present as single birds or small numbers at one or two sites (Table 1).

Of particular interest is the presence of male and female Blue-billed Ducks on 27 June 2002 in the north-east of the lake with the male in breeding plumage. Blue-billed Duck is rarely recorded in the arid interior and the Top End of Australia. None have been reported from Lake Gregory (Halse *et al.* 1998). Marchant and Higgins (1990) report only one Northern Territory record and the nearest records in Barrett *et al.* (2003) are at Alice Springs and Glen Helen Gorge in central Australia.

The record for Magpie Goose extends its known southern distribution in this part of the Northern Territory although they have been recorded from just across the border in Western Australia (Barrett *et al.* 2003) and also occur at Lake Gregory (Halse *et al.* 1998). The presence of Great Crested Grebe and Purple Swamphen at Lake Nongra adds an additional locality to their sparse distribution in the Northern Territory and arid northern Western Australia (Marchant & Higgins 1990, 1993, Barrett *et al.* 2003). The other waterbirds recorded have widespread distributions and their presence at Lake Nongra is not unexpected.

The only birds observed breeding were a pair of Masked Lapwing (2 eggs).

Waterbirds not recorded by me but reported by Jaensch (1994) are Plumed Whistling-Duck, Nankeen Night Heron, Australian White Ibis, Baillon's Crake, and Clamorous Reed-Warbler. The latter two species were seen in the north-west part of the lake, an area not visited by me.

The total number of waterbirds recorded by Jaensch (1994) was 1880. It is not possible from my observations to estimate waterbird numbers for the whole lake, however it is clear that there were many more birds present than during the 1993 survey. During the first of the southern October-November 2002 surveys there were about 2000 waterbirds in the southernmost ~1.0 km of the lake. Many additional birds are likely to have been present elsewhere in the lake, particularly in the north-west part where several major creeks enter and where trees appear to extend well into the lake.

The apparently low numbers of waterbirds recorded by Jaensch (1994) at Lake Nongra in early-mid 1993 corresponds to the lowest numbers recorded at Lake Gregory in the period 1988 to 1995 (4376 in 1993 compared to 44 141–650 000 in seven other surveys, Halse *et al.* 1998). This was a wet year and birds were likely to have been widely dispersed. This suggests that higher numbers than recorded by Jaensch (1994) might normally be expected at Lake Nongra, at least when the lake is not dry.

Bushbirds

Most bushbirds recorded around the lake margins have widespread distributions. However, Red-tailed Black-Cockatoo (subspecies *macrorhynchus*), Little Friarbird, Yellow-tinted Honeyeater and Rufous-throated Honeyeater are at or close to the known inland edge of their range. The lake also marks the approximate southern boundary for Grey-fronted Honeyeater, Jacky Winter and Restless Flycatcher which do not extend into the Tanami Desert, although these birds also occupy more southerly regions elsewhere. Lake Nongra is close to the known northern limit for Spiny-cheeked Honeyeater at this longitude (Blakers *et al.* 1984, Barrett *et al.* 2003).

Lake Nongra is a large isolated wetland within a semi-arid terrain and probably has regional significance for waterbirds. The apparently high numbers of waterbirds present in 2002 compared to 1993 may reflect the use of the lake as a drought refuge given the very dry conditions experienced in the area during 2001-2002. Seventy-three waterbirds have been recorded from Lake Gregory, a similarly situated and regionally significant wetland, so future surveys at Lake Nongra are likely to record many additional species.

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Although common in coastal areas of the Northern Territory, the Magpie Goose *Anseranas semipalmata* is infrequently seen as far inland as Lake Nongra. (Martin Armstrong)

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Use of tree hollows by the Green Tree Frog *Litoria caerulea* at East Point Reserve, Darwin

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The Green Tree Frog *Litoria caerulea* has one of the broadest geographical ranges of all Australian hylids. Its distribution extends in a wide arc from south of Broome (Anna Plains) through the Kimberley, across the Top End south and inland to the Tanami, Sturt Plateau and Barkly Tableland, and down the east coast through Queensland to northern New South Wales (Barker *et al.* 1995, Tyler *et al.* 1983, P. Horner, pers. comm.). It is also extralimital in New Guinea (Tyler 1999). The three other species in the *Litoria caerulea* complex each have relatively restricted distributions. *Litoria gilleni* occurs in the central Australian ranges (MacDonnells), *Litoria splendida* in the East Kimberley and Keep River region, and *Litoria cavernicola* is a habitat specialist confined to the Mitchell Plateau of the Kimberley. *Litoria gilleni* was originally described by Spencer (1896) and is currently considered a good species (*e.g.* Cogger *et al.* 1983, Bedford 2000), as are *L. cavernicola* (Tyler & Davies 1979) and *L. splendida* (Tyler *et al.* 1977). Tyler and Davies (1986) included *L. gilleni* under *L. caerulea* which was noted as occurring "throughout the Northern Territory".

Whilst the three geographically restricted members of the *Litoria caerulea* complex are largely or exclusively rock dwelling (saxicoline) species that use moist microclimates in rock crevices (often near sources of permanent water) as retreats, *L. caerulea* uses tree hollows as shelter sites across its range. It occurs in a wide range of habitats including savanna, pindan, eucalypt woodlands and forests, closed monsoon forests and thickets, and has also been recorded from mangroves (J. Smith, pers. comm.) and mango orchards (R. Peng, pers. comm.). In many parts of Australia, including the Top End, it has become accustomed to human habitation and commonly breeds in garden ponds.

As part of ongoing physiological studies of Top End amphibians, I have been involved in investigations of the biology of *L. caerulea,* with the focus of the work at East Point Reserve near Darwin. The Reserve includes a mosaic of grassed and revegetated areas, with a single patch of relatively undisturbed coastal rainforest occupying an area of approximately 25 ha within which the studies have been conducted. The vegetation at the study site is defined as a low closed coastal dry monsoon forest (*sensu* Russell-Smith 1991). It consists of a mixed array of trees, shrubs and vines including many Malesian floral elements and generally extends to a height of 9–12 metres. Conditions under the dense rainforest canopy are highly suited

to tree frogs, incorporating extensive shade, warm and relatively constant temperatures, high humidity, and minimal air movement particularly near the forest floor (McCay 2003). These last two factors in particular serve to reduce rates of evaporative water loss (e.g. Christian & Parry 1997, Tracy 1976) in what is a seasonally dry (monsoonal) and therefore potentially highly desiccating environment.

At East Point the frogs are primarily active during the wet season. They are probably entirely nocturnal, emerging soon after dusk and moving to the canopy, the forest floor or low perches on branches. Breeding takes place opportunistically during the wet season, calling activity being particularly intense during heavy rain. Frogs tend to remain within tree hollows during the coolest months of the dry season (G. Miles, pers. comm.), but are relatively active when weather conditions are suitable, i.e. during periods of high night time humidity or warmer weather.

One aspect of the investigations at East Point has been to examine the use of daytime refuges by *L. caerulea.* Individual frogs have been followed to their daytime refuges with the aid of radio-tracking (telemetry) techniques, and a pattern of use of hollows has emerged. Frogs that were tracked were given a unique identification number or code, and tree hollows were numbered after a frog had been followed and the location of the hollow determined. In certain instances, where hollows were high above the ground, the tree species could be identified but it was not possible to measure the attributes of the hollow.

Tree species that form hollows were identified using Brock (1997), Wightman and Andrews (1989) and Booth *et al.* (2001) and with reference to collections maintained at the Northern Territory (NT) Herbarium. A list of plant species for the area was derived from NT Herbarium records and Wightman and Andrews (1989). Based on this information, approximately 140 plant species occur in the monsoon forest at East Point (excluding artificial plantings). This includes 48 species of tree (defined as plants with a robust trunk and capable of exceeding five metres in height), only nine of which are utilised by the frogs as daytime refuges (Table 1). Several trees of *Litsea glutinosa, Drypetes deplanchei* and *Ganophyllum falcatum* were used as hollows, whereas for the remaining six species there were only single cases of hollow use (Table 1).

Only certain types of trees in the monsoon forest readily form hollows, and of these only some appear to be suitable as refuge sites for frogs. Hollows vary in structure as a result of their mode of formation. In *Litsea glutinosa* knots form at regular intervals along the trunk at previous points of attachment for branches and become small hollows; hollows also form in the trunk of dead individuals of this species (Table 1). Convolutions of the trunk in *Drypetes deplanchei* form a vertical envelope or fissure of varying extent which may become almost entirely enclosed. Hollows of this type tend to be larger but probably do not provide as much protection as closed hollows. *Ganophyllum falcatum* forms cylindrical hollows along main branches, some of which are many metres above the ground. Dead and decaying trees are also used and termites

are an important agent of hollow formation. However, our data indicate that trees are not utilised by frogs after they have fallen to the ground.

Table 1. Characteristics of trees with hollows that were utilised as daytime refuges by *Litoria caerulea* at East Point Reserve (n = 25 hollows). (H = Hollow number, Frog ID = identification number or code of frog/s that used the hollow)

H	Frog ID	Tree species	DBH (cm)	Height (m)
1	10, X	*Litsea glutinosa*	10	9
7	D	*Litsea glutinosa*	6	7
22	11	*Litsea glutinosa*	10	6
25	11	*Litsea glutinosa*	25	10
26	11	*Litsea glutinosa*	15	9
27	11	*Litsea glutinosa*	12	12
2	A	*Drypetes deplanchei*	22	10
3	B	*Drypetes deplanchei*	20	10
5	C	*Drypetes deplanchei*	25	11
9	9	*Drypetes deplanchei*	20	9
23	11	*Drypetes deplanchei*	21	9
6	10, 8	*Ganophyllum falcatum*	60	14
10	2	*Ganophyllum falcatum*	30	11
11	8	*Ganophyllum falcatum*	50	10
16	8	*Ganophyllum falcatum*	30	12
18	11	*Denhamia obscura*	16	9
20	15, 13	*Pouteria sericea*	12	9
14	8	*Miliusa brahei*	20	10
17	11, X	*Polyalthia nitidissima*	16	9
15	7, 16	*Strychnos lucida*	20	9
21	7	*Acacia auriculiformis*	40	16
4	2, 12	dead *Litsea*	7	7
8	4	mostly dead	20	11
19	17	termite ridden	8	7
X	X	dead slender tree (*Litsea* ?)	10	5

Trees used by Green Tree Frogs display a wide range of characteristics, from tall trees with dense foliage to low spreading species (Table 2), although the majority of trees are greater than seven metres in height (Table 1). There are also a range of bark types from smooth to fissured. As in other dry monsoon forests of the Northern Territory, a subset of the vegetation is deciduous during the dry season (Bach 2002). As a consequence, vegetative cover is less adequate and there is greater penetration of sunlight and potential for air movement during the dry season. These factors are likely to increase the importance of tree hollows as daytime refugia during this period.

Table 2. Characteristics of hollow-forming tree species used by *Litoria caerulea.*

Tree Species	Max. height (m)	Habit	Bark	Foliage	Leaf retention
Acacia auriculiformis	20	tall spreading	rough; fissured at base	dense	evergreen
Denhamia obscura	10	rounded crown	rough	pendulous	evergreen
Drypetes deplanchei	12	upright buttressed	smooth to slightly rough	dense	semi-deciduous
Ganophyllum falcatum	20	large tree	smooth to slightly coarse; flaking	dense	evergreen
Litsea glutinosa	15	slender upright	smooth to slightly rough	moderately dense	deciduous ?facultatively
Miliusa brahei	15	erect	rough, fissured	moderately dense	deciduous
Polyalthia nitidissima	20	upright	slightly rough	dense	evergreen
Pouteria sericea	10	erect	rough, finely fissured	moderately dense	evergreen
Strychnos lucida	6	low spreading	smooth to slightly rough	moderately sparse	facultatively deciduous

Hollows used by *L. caerulea* vary considerably in depth, from 8 to 30 cm, but the width of the opening is consistently less than 4 cm (Table 3). The majority of trees used are greater than 9 cm diameter at breast height (DBH: Table 1). Hollows are generally at head height or above, although they may be quite low, eg. Hollow 1 (Table 3). I have

only managed to record measurements for a subset of the hollows because several were inaccessible or the exact location could not be identified using radio-tracking techniques (Table 3), hence it is likely that the data are biased in favour of hollows nearer the ground (cf. Griffiths 1994).

Consideration of the microhabitat requirements of *L. caerulea* suggests that optimal hollows are likely to be those that retard moisture loss and secondarily may also reduce vulnerability to predators and competitors. A tight-fitting hollow is presumably optimal for maintaining moisture balance and in some situations the head of the animal may block the hollow; this may serve to reduce water loss and may also discourage predators. Potential predators at East Point include Children's Python *Liasis childreni,* Common Tree Snake *Dendrelaphis punctulata,* Slaty-grey Snake *Stegonotus cucullatus,* the monitor lizards *Varanus panoptes* and *V. scalaris,* and Pacific Baza *Aviceda subcristata.* Some hollows retain water during the wet season and the frogs have been observed to conceal themselves underwater when approached. Frogs also use man-made structures (ablution blocks) at East Point, which provide suitable shelter and moisture conditions.

Table 3. Characteristics of tree hollows used by *Litoria caerulea* at East Point Reserve. Tree species are listed in Table 1. Hollows 20u, 16, 21, and additional hollows (not listed) were inaccessible or could not be located precisely. l and u denote lower and upper respectively.

Hollow No.	Height above ground (m)	Width of opening (cm)	Hollow depth (cm)	Orientation	Hollow Type
11	6	4	10	diagonal	branch
15l	4	3	10	horizontal	trunk
15u	4.5	2.5	8	vertical	trunk
4	3	4	9	vertical	dead hollow trunk
1	0.6	1.5	4	vertical	slit/knot
17	1.6	2	10	vertical	in fork
2	2	1.5	30	vertical	fissure
23	1.5	2	8?	vertical	fissure
20l	4	2	8	vertical	trunk knot
20u	4+	?	?	?	knot ?
26	2.1	2	8	vertical	in fork
16	5+	?	?	?	branch ?
21	5+	?	?	?	?
X	1.1	5	20+	vertical	hollow trunk

On two occasions we have recorded two individuals using different hollows in the same tree, and at times we have observed two frogs using the same hollow. The choice of hollow may indicate individual preference for particular tree species; certainly it appears to be the case that distinct hollow types are selected by individual animals. A visual search of potentially suitable hollows was made in a portion of the forest, and a low level of occupancy was found, suggesting that frogs are selecting particular types of hollows as shelter sites. Surveys of tree frequency (unpubl. data) indicate that of the commonly utilised species *Litsea glutinosa* is relatively abundant in the forest patch at East Point, whereas, for example, *Ganophyllum falcatum* occurs at low densities. Also, although stem densities are exceedingly high (approximately 9000/ha), average DBH is low (Mean ± SD (cm): 5.55 ± 3.98) with few stems ≥ 9 cm DBH (~20%), and of these only some appear to have the potential to form hollows.

Green Tree Frogs appear also to use tree hollows in woodland habitats (often near water), but there is no data on the types of shelter sites in the range of other habitats that they occupy. In addition, I am yet to confirm whether (as I suspect) densities are highest in areas of moist microclimate such as rainforest patches. Finally, although Green Tree Frogs are widespread, common and frequently encountered, this study represents what is effectively the limit of the knowledge of the ecology of the species. Further research is required to describe the basic biology of this species, and indeed much of the Torresian herpetofauna.

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The Green Tree Frog *Litoria caerulea* is active both on the ground and in trees. (Paul Horner)

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